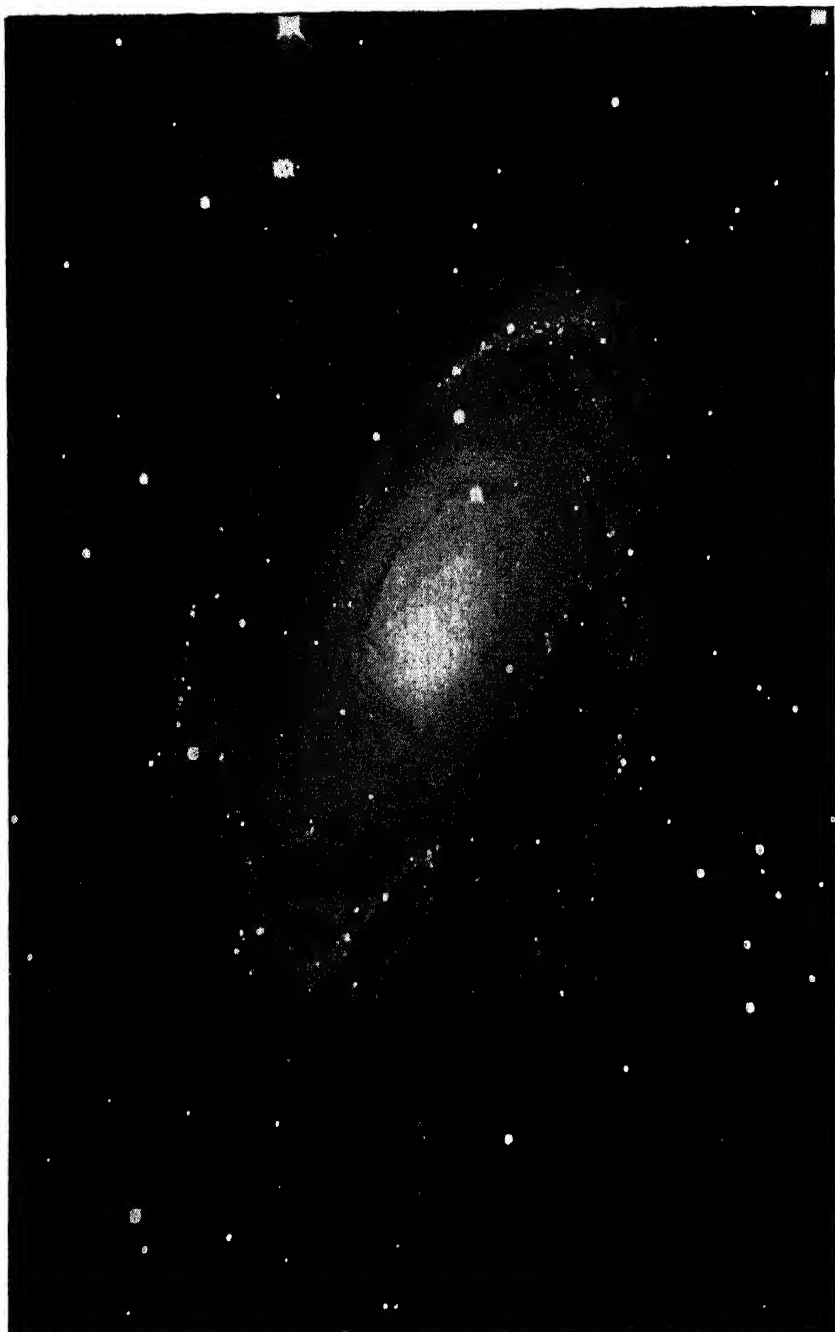


ASTRONOMY



This galaxy, composed of stars like ours, we now see as it appeared more than a million years ago. Who can say what it is like now?—
Photographed at Mount Wilson Observatory.

ASTRONOMY

THE SPLENDOR OF THE HEAVENS
BROUGHT DOWN TO EARTH

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Drawings by Claude H. Dyer



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Foreword

SPEED is a characteristic of the age. With science at the throttle, we can forecast the possibility of inter-planetary travel. Man has hurtled through space at a rate of more than 440 miles per hour. Even if he could go a thousand times that fast he could not reach another sun within a hundred years, even though that terrific speed was never for an instant slackened. The winged feet of modern Mercury must be exchanged for the speed of lightning if we are ever to leave our world and explore the worlds we see as small dots in the sky.

Let us, however, go on a celestial journey in an imaginary machine we shall call a "radio plane," which travels through space on the crest of a radio wave. After one of our powerful broadcasting stations has pushed us off at the rate of 186,000 miles per second, we are on our way to learn more about our neighbors who live in other parts of space.

In less than two seconds we have passed the moon and the spinning earth is now so far away that we can scarcely recognize London, New York, Chicago, and San Francisco for what they really are. In about eight minutes we come to the sun and in less than six hours we have passed each of the other worlds in turn and have arrived at the outskirts of the sun's domain. The sun is still visible, but it looks like a star, and most of the nine worlds with their twenty-six moons have long ago disappeared from view.

We have lost our sun, but perhaps we can find another one.

With our radio plane pointed at Proxima—the nearest sun to ours—we fly on, traveling six million, million miles every year and finally, after spending four years, four months and seven days in the cold and dreary depths of space, we feel the warmth and enjoy the light of another sun. We are now thirty million, million miles from home and the sun that once kept us warm shines very faintly as a dim star. The planets that moved about among the stars in our sky at home have long since disappeared from view, but Proxima also has worlds revolving about it. Perhaps some of Proxima's worlds are inhabited. At any rate we can amuse ourselves by studying these strange planets.

But our journey has hardly begun. We must go on. We remember how we used to admire the brilliant Dog Star—Sirius—which nightly trails at the heels of the celebrated hunter Orion as he moves so majestically across the sky. We are off for the brilliant Sirius. Here is an opportunity to examine that little world revolving about the Dog Star, whose material is so heavy that one cubic inch weighs a ton. On and on we ride, our radio plane passing one sun after another until, after thirty-three thousand years, we find ourselves in the Milky Way in the outskirts of our galaxy.

But we cannot stop here. On goes the radio wave and our plane must go with it. There are other galaxies to explore. There is one over yonder not so very far away. It looks very much like that spiral nebula we used to see in the direction of Andromeda. On we go toward this neighboring galaxy. Our sun and the familiar constellations have disappeared long ago and our galaxy has now folded up until it resembles one of those objects we once called spiral nebulas.

After 900,000 years we find ourselves "broadcasted" into the Andromeda Galaxy and surrounded by many strange constellations. As we approached this galaxy it lost its spiral shape. We are now within it and its stars are scattered about in every direction. What a beautiful Milky Way! And how it resembles the one we used to admire at home!

On and on we fly. Centuries come and go, new worlds are born and die and still our radio plane has not reached the end of the galaxies. Surely "these are but part of His ways, and the thunder of His power who can understand?"

But why take even a few hours out of a busy life for this

imaginary trip through space? We may indeed learn something about our neighbors, but how can this be of any benefit to us? A knowledge of the physical conditions and of the movements of the other worlds may have some cultural value, but how can it possibly make any practical contribution to the happiness and contentment of the human race?

How could we operate our railroads? Our broadcasting chains? In fact, how could we even live in this twentieth-century civilization if we were not able to determine the exact time at any instant? But where do we get our time? Not from the doctor, the lawyer, the preacher, the banker, the power magnate, the business executive, the physicist, or the chemist, but from the astronomer who daily regulates our clocks by the stars. We all agree that science has made many contributions to our happiness, but much scientific progress, even including the newly discovered radio, has been the direct result of astronomical investigations.

Thomas Jefferson once said, "An educated man is a man who understands what is going on in the world and is able to keep his part of it going right." Then how can a man claim to be educated if he knows nothing about any part of the universe except a very limited region in which he happens to live? How can he claim to understand what is going on in his own little world if he cannot tell you how exact time is determined and where the regulating clock is located?

For our little excursion among the other worlds we need no laboratory. Nature has already attended to this. There is no place on the earth where the sun, the moon and some of the familiar constellations do not constantly pass in review. We may try as hard as we please but it is absolutely impossible for us to get out of our natural astronomical laboratory as long as we live.

Do you ever play the fascinating game of "star-gazing" with your children—almost the only game the modern parent can play with his child? Children are eager to understand what is going on about them and they naturally ask many questions about their universe. Are you ever called upon to answer such questions? Are you puzzled when they inquire about the seasons? Can you explain to the satisfaction of your child why longitude is measured from Greenwich? Where is the sun at midnight? Why are the days longer in the summer than in the winter? Why do we have the cold winter season when we are

closest to the sun? Why does the moon rise in a different place every evening and go through its monthly phases? Why does each star rise about four minutes earlier every evening?

Let us begin our imaginary trip by taking a short tour around the earth. We will then go farther and farther into the depths of space and when we finish the last chapter we will be true citizens of the universe, with our mental horizon widened to such an extent that we can recognize the marvelous unity of matter, of energy and of God.

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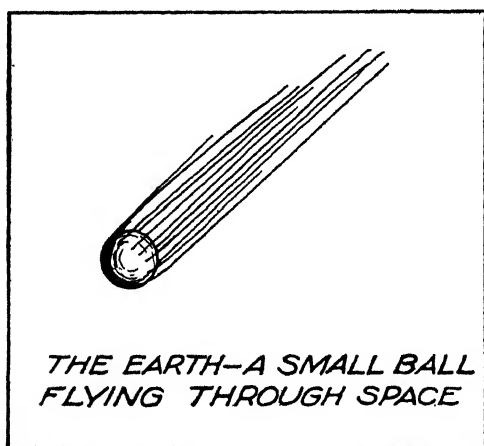
ASTRONOMY

CHAPTER I

Our Flying World

THE EARTH AN INSIGNIFICANT SPHERE 8,000 MILES IN DIAMETER

ALL primitive peoples felt that the earth was the center of the universe and the object of creation. In fact they believed that were it not for the earth there would be no sun, moon or stars in the sky because they would not be needed. One by one these crude notions about the importance of the earth in the scheme of the universe have given way to the revelations of science until we are convinced that our earth is a little insignificant ball about 8,000 miles in diameter whose complete destruction would have



very little, if any, effect on the universe. In other words, if the earth should be thrown out of the universe at this instant, its disappearance would have no noticeable effect on anything in the sky except the moon. Everything else would move along just as it is moving today.

All down through the ages people have attempted to answer the many questions that men have asked about the earth. How old is it? What is its shape? What holds it up? Is it fixed or does it move? What is its position in the universe?

When the human race was in its infancy man's efforts at a solution of these perplexing problems were naturally very crude and certain erroneous ideas were accepted as true. When some scientist, or philosopher, who happened to be able to think and reason several centuries beyond his fellowmen, proposed a correct answer to one of these questions he was usually ridiculed and in some instances he was actually put to death.

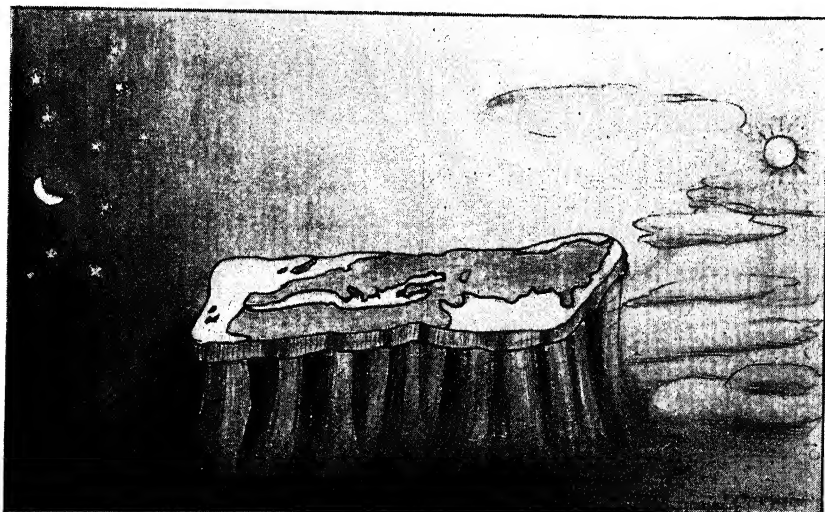
How old is the earth? It is only recently that the earth has given us any definite information with reference to her age. According to the legends of the early Hebrews the world was created in the year 4004 B. C., but we now know that at that time man had been on the earth several hundred thousand years and that the cities of Egypt were then crowded with people, and beyond man stretches an endless chain of varied forms of living beings, back to the very origin of life.

Geologists have always claimed that the oceans have been on the earth at least a hundred million years and now the chemists, from evidence found in a vein of lead in Norway, tell us that the earth is at least nine hundred million years old. Such a figure is hard to grasp, but the earth is probably much older than that.

PRIMITIVE PEOPLES LIVED ON A FLAT EARTH

What is the shape of the earth? This question has been answered in various ways by different races of people and even in the twentieth century one sometimes hears echoes of the old argument as to whether the earth is round or flat. We have all heard of the young woman who went before a school board seeking a position as teacher in a one-room school in the mountains. She was out of work and was very anxious to secure this position at any cost so when one of the school directors asked her, "Do you teach that the earth is round or that the earth is flat?" she replied, "Oh, just give me the job. I'll teach it either way."

The primitive conception of the earth seems to have been that of a flat plain, covered by a hemispherical dome, known as the sky, which was in turn supported by the mountains. This was indeed a very natural belief. Among those peoples who believed they were living on a flat earth were the Aryans, Chaldeans, Egyptians, Babylonians, and early Hebrews.



Our primitive ancestors lived on a flat earth.

The Chaldeans believed that the earth was flat and rested upon the waters. Inside of the earth was the realm of the dead and above the earth was the firmament. On the east and west sides of the firmament were doors for the convenience of the sun and the moon and above the firmament was another ocean.

The early Egyptians thought that the earth was flat and oblong and at each of its four corners was a pillar which supported the sky. The "waters above the firmament" were on top of the sky and frequently escaped through "the windows of heaven." From the underside of the firmament were suspended the stars and other heavenly bodies for the convenience of man.

The early Hebrews believed that the earth was flat and resting on water. There was water under the earth and there was water above the earth, which was held back by the firmament. In the firmament were windows which were opened and closed by angels to allow the rain to fall upon the earth. Some of the early peoples who could not agree with the Hebrews that the earth

was floating in water believed that the earth was flat and that on the under side of the earth were many roots which extended down into—well, they did not say what!

WISE MEN OF EARLY DAYS ARGUED AS TO SHAPE OF EARTH

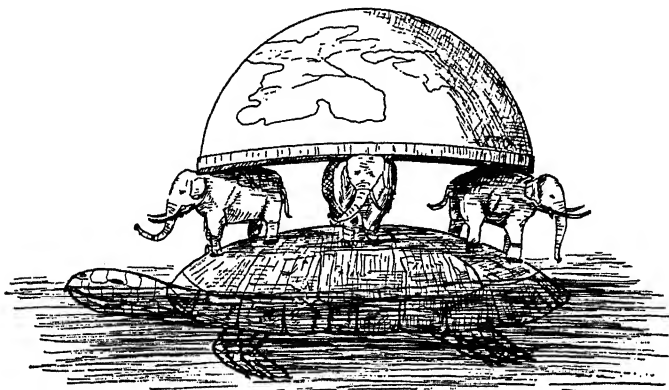
Some of the leading thinkers of early times believed that the earth had the shape of a sphere. Among these were Homer, Thales, Pythagoras, Aristotle, Ptolemy, and Eratosthenes, who even computed the circumference of the earth about 250 B. C., missing the correct result by only 100 miles. A Sanscrit treatise is said to be in existence which clearly states that the earth is a globe and unsupported.

The philosopher Plato could not agree with the other leaders of Greek thought and argued that the earth, being the creation of the Almighty, must be perfect and, since the smallest perfect number is six, the earth must have six sides. A perfect number is equal to the sum of its factors. For example, the number six is divisible by one, two, and three and the sum of these three factors is six. The next perfect number is twenty-eight which is divisible by one, two, four, seven, and fourteen, the sum of these factors being twenty-eight.

The Hindus had some very crude ideas about the shape of the earth. Many of them thought that the earth was in the form of a hemisphere and was supported by four large elephants. This seems to have been entirely satisfactory until some one asked what was holding the elephants up. After some discussion the wise men of India agreed that these four elephants were standing on an immense mud turtle. Again the people seem to have been satisfied until some inquisitive person raised the question as to what was holding the mud turtle up. I imagine the philosophers had grown tired of answering these questions by this time for they are said to have replied that there was mud under the mud turtle and there was mud all the rest of the way.

Although there is no statement in the Old Testament to the effect that the earth is flat, many early Christian writers considered it their duty to prove that the earth was not round. One

of the most interesting attempts of this kind was that of Cosmas who proposed a very elaborate theory and wrote several books during the sixth century. He taught that the earth had the shape of the tabernacle of Moses and that there was a tall mountain



The Hindu earth was supported by elephants, a mud turtle, and then mud, mud, mud.

in the north behind which the sun went at night, disappearing on the western side and re-appearing on the eastern side the next morning.

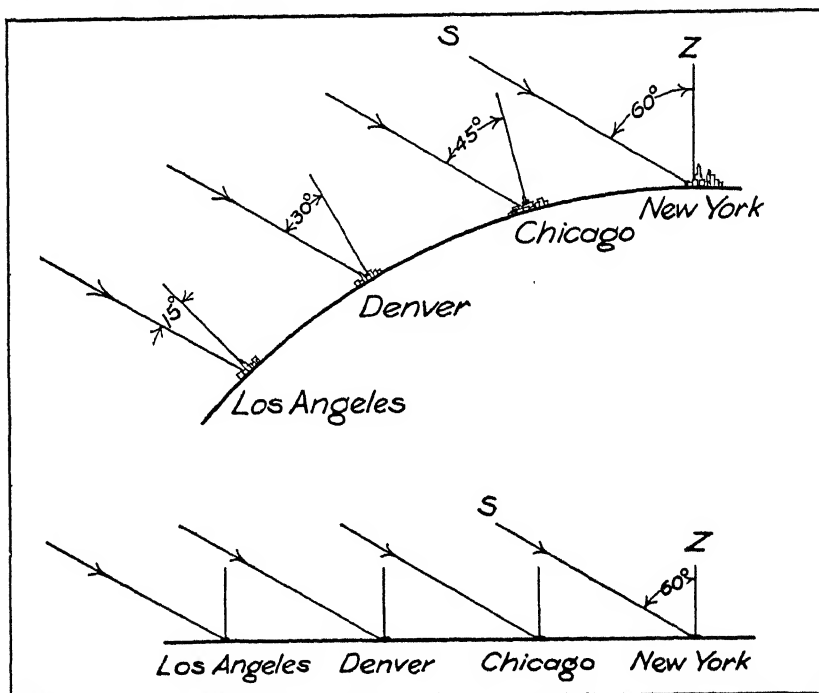
SCIENTISTS HAVE CONVINCED MOST PEOPLE THAT EARTH IS ROUND

The Greek philosophers vainly attempted to convince the masses that the earth was round, but this idea was accepted by only a few educated people who passed it down through the ages. It met with violent opposition for about fifteen centuries and even after Columbus and his associates had set sail on the search for a new world, few of their friends expected to ever see them again for they would surely drop off of the edge of the earth.

Of course, every school boy now knows that the earth is round even if he does not know how to prove it. A teacher once asked a bright boy to give three reasons why he knew that the earth was round. His answer was, "Ma says so, Pa says so, and now you say so." The average person knows that the earth is round, "because ships have sailed around it." This is no proof at all. The

earth might have the shape of a cucumber and ships might still sail around it. When the shadow of the earth is thrown upon the moon it always has an elliptical shape. Since such a shadow could be cast only by a round object we have here a very convincing proof.

Another proof that the earth is round is the fact that time is different at different places on the earth. If you will listen for time-signals that are broadcast daily by radio stations you will hear an announcement from New York City that it is now four



When the sun is sixty degrees past the meridian in New York it is only forty-five degrees past in Chicago, and the two cities have different times. On a flat earth every city would have exactly the same time at any instant.

o'clock. Then another announcer in Chicago may say that it is two minutes after three o'clock. If you will then pick up a Denver station you may learn that it is five minutes after two o'clock and immediately thereafter you may be told by an announcer in Los Angeles that it is six minutes after one o'clock. Each announcement is correct at the place where it is made. They differ because

the earth is round. On a flat earth we would have no need for standard time for when it was four o'clock in New York City it would be four o'clock over the entire earth.

We know that the world is round because the North Star and the constellations rise and fall as we change our latitude. Besides, we can see that all the other worlds are round, then why should ours be flat?

THE MISSISSIPPI RIVER RUNS UP-HILL

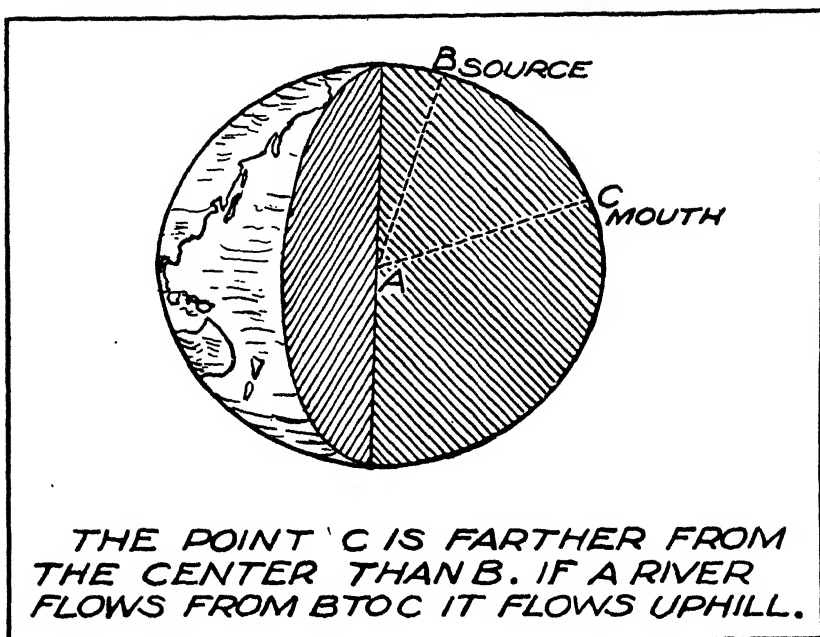
We usually say that the earth is round, but this is not quite true. On account of its rapid rotation the earth is somewhat flattened at the poles. If this were not true all the water would be piled up along the equator and there would be no ocean near either pole.

Every rotating planet seems to have adjusted its shape to its rotation through the influence of the law of gravitation. The faster a planet rotates the flatter it becomes. This flattening is especially noticeable in the case of the planets Jupiter and Saturn which rotate much more rapidly than the earth.

The people in the torrid zone and in the temperate zones are farther from the center of the earth than those living nearer the poles. We have been taught that water always runs down hill, but the Mississippi and several other large rivers of the earth actually run up-hill. The mouth of the Mississippi is much farther from the center of the earth than the source and, if the earth should stop rotating, the river would run toward the north. It is the rotation of the earth that makes it run up-hill toward the south.

We should not conclude that our little world lacks much of being a perfect sphere. It is true that the polar diameter is only 7900 miles in length while the equatorial diameter has a length of 7927 miles, so that when you are at one of the poles you are $13\frac{1}{2}$ miles nearer the center than when you are on the equator. However, this difference is so small in comparison with the actual diameter that the earth would appear as round and as smooth as a billiard ball to an observer from a distance.

We sometimes refer to our tall mountains whose peaks extend



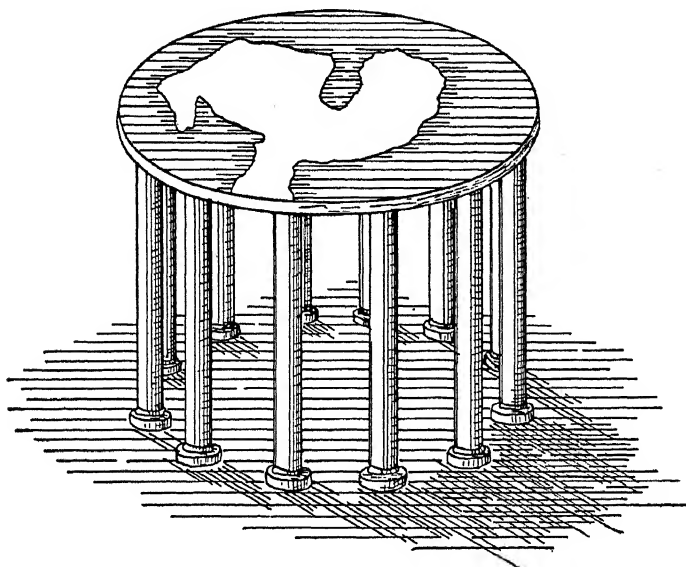
to a height of five miles above sea level and to our deep oceans whose bottoms lie five or six miles below their surface, but the words "tall" and "deep" are relative terms which lose their significance when the standard of comparison is changed. As a matter of fact if all of the mountains should be taken off the earth and all the water in the oceans should evaporate, the change in the size and shape of our world would not be greater than that made in a wet football by wiping it dry.

THE EARTH IS RESTING UPON NOTHING

What holds the earth up? The author of Job (26, 7) answers, "He stretched out the north over the empty place and hangeth the earth upon nothing." No scientific statement could be more accurate than the last part of this sentence. What a pity that those early leaders who insisted upon a literal interpretation of the scriptures overlooked this statement, which means exactly what it says. A literal interpretation of this verse in the Book of Job would have eliminated much discussion and saved much time

which might have been devoted to something more worth while.

The early Vedic priests solved the problem of the support of the earth in a very interesting manner. They represented the earth as a flat disc like a silver dollar, supported by twelve pillars placed at equal intervals around the edge. They explained



Twelve pillars supported the earth of the early Vedic priests. This left plenty of room for the sun and the moon to go down under the earth and then come up again on the other side.

that the earth would last just as long as the pillars would hold it up. They even taught that, if the people did not do their religious duty and make reasonable financial contributions, these pillars would crumble and, if an earthquake happened to occur at any place, they could always point out exactly which one of the pillars was crumbling and just why it was in that condition.

Of course this crude idea, as well as the others that were invented for the purpose of finding supports for the earth, could not survive after Newton discovered the Law of Gravitation and proved the truth of Kepler's laws of planetary motion. We now know that the earth does not need any supports because it is held in its proper place by the invisible chains of gravitation even more firmly and securely than if it were imbedded in solid rock.

A little reflection will convince one that the question as to what holds the earth up does not need an answer. Since the earth is round we wonder which way it could fall. We would, of course, expect it to fall downward, that is, toward the center of the earth. However, people who are living on the opposite side of the earth would also expect it to fall downward and the direction which they denote by "downward" is just exactly the same direction as we would denote by "upward." In other words, no matter in what direction the earth might fall this direction would be upward for some one.

EVERY EARLY NATION LIVED AT THE CENTER OF THE EARTH

Primitive man had very crude ideas about his position on the earth so that many curious maps of the earth's surface have been handed down to us. Every race of people naturally felt that they were living at the center of the earth's surface. The northern tribes believed they were living in the central region which they called Medgard. For the Hindus the center was Mount Meru, for the Assyrians it was Babylon, and for the Greeks it was Mount Olympus. The Chinese have always referred to their country as the Central Empire and the Hebrews considered Jerusalem to be the center of the earth. In fact, in the Book of Ezekiel (5, 5) it is written: "This is Jerusalem: I have set it in the midst of the nations and countries round about her."

Although we may laugh at the crude ideas of these people about their position on the surface of the earth, we will have to admit that even in modern times we have exactly the same ideas with reference to our own position. Of course we know that the earth is round and not flat. However, if you should draw a picture of a round earth and then indicate by a point on its surface the place where you happen to be standing would you not naturally put yourself at the highest point of the circle? In other words, as we look about over the landscape do we not feel that we are "sitting on top of the world?" That is, our visible horizon appears to be a flat plane of circular shape and we imagine ourselves at the center of it.

During the centuries which have passed since the discoveries of Columbus we have gradually learned more and more about the surface of this little globe upon which we live, and maps of the different parts of the earth are now fairly accurate. In fact they are probably as accurate as can be expected since no flat map can represent accurately the surface of the earth. We should keep in mind, however, that the task has not yet been completed. We have so little accurate information at this time with reference to the surface of the north frigid zone and the south frigid zone that maps of these parts of the earth are not as accurate as maps of some parts of the moon.

OUR ANCESTORS DREW VERY CURIOUS MAPS OF THE EARTH

In olden times people had no means of rapid communication and consequently each race lived to itself and had very little information about other parts of the earth. Under such conditions it was impossible even for an educated man to draw a correct map of the different countries on the earth.

Each race felt sure that its capital city was in the exact center of the earth and all their crude maps were so drawn. The early church accepted the Hebrew belief as stated in the Book of Ezekiel, that Jerusalem was in the center of the earth, and all of the early maps prepared by the church show this city in that position. A very curious map was prepared by a monk by the name of Cosmas during the sixth century. On this map we find Europe, Asia, and Africa and also the Tigris and Euphrates rivers and the Arabian gulf. On the four sides of this map we discover very curious faces with inflated cheeks representing the four winds of heaven.

Another very curious map dates from the eighth century. Here the earth is represented by a circular disc with Jerusalem at the center. We also find Europe and Asia, with England and Scotland on the extreme edge of the disc. On all maps of this period east was represented at the top. This was very probably due to the fact that all early peoples were sun worshippers and the most important direction was toward the rising sun. On the

map mentioned above are curious pictures of Adam and Eve and the serpent near the top because the Garden of Eden was supposed to be in the east. On this map the earth was completely surrounded by a river which was usually referred to as the River Ocean. It is in this river that we find England and Scotland.

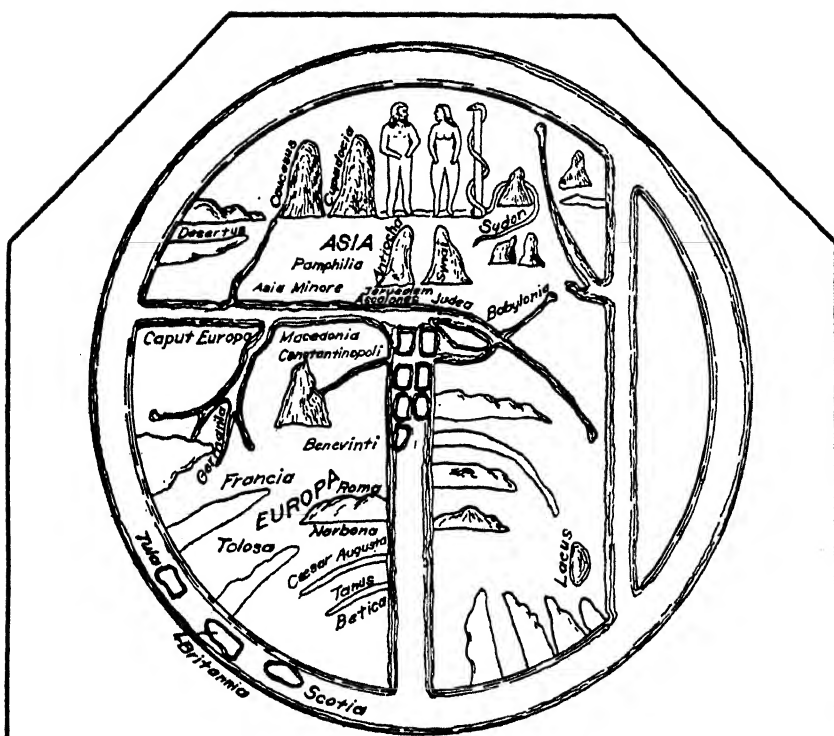
Even after the great traveller Marco Polo had reported the results of his explorations at the end of the fourteenth century and most people were agreed that the earth was round the maps of the earth were still very crude. There is one noted map which dates from the sixteenth century on which the earth is represented as a sphere with a crank at each pole. An angel was on duty at each of these cranks in order to take care of the rotation of the earth.

PRIMITIVE PEOPLES ATTEMPTED TO LOCATE THE ABODES OF DEPARTED SPIRITS

In addition to their crude maps of the inhabited part of the earth all primitive peoples had their legends about the existence somewhere inside the earth of a place of torment where mortal man paid the penalty for his sins on earth, and another region where the blessed lived in eternal happiness. No two nations could agree as to the location of these regions, but all believed in their existence.

The Greek and Roman poets gave many detailed descriptions of the place of torment which Homer called Tartarus. There lived the Titans, the enemies of the gods. Some writers painted very detailed pictures of the Underworld. They even determined the depth of Tartarus and described its rivers, its lakes and mountains. From classical mythology we learn that Tartarus was presided over by Pluto, whose very name was sufficient to cause mortal man to tremble with fear. At the gate of Tartarus Pluto stationed a three-headed dog, Cerberus, to prevent mortals from entering and spirits from escaping.

Near the throne of Pluto sat the three Fates. The youngest of the three sisters spun the thread of life, the second twisted it, and the third cut it off with a huge pair of shears whenever it was



An Eighth Century Map of the World

Earth beyond the ocean where men dwelt before the deluge



A map prepared by Cosmas during the sixth century.

time to bring another soul into the infernal regions. When the gates were opened to receive a victim the air was filled with the groans and cries of those within who were receiving just punishment for their sins on the earth.

The northern tribes believed in the existence of a remote region somewhere which was the abode of the gods. This region they called Asgard. They also had crude ideas about the existence of subterranean caverns inhabited by dwarfs and pigmies and presided over by the goddess Hel.

The great Italian poet, Dante, in his Divine Comedy presents a vivid picture of the Underworld as it appeared to his lively imagination. Dante made an imaginary trip through all of Hades and gives us a vivid account of what he encountered.

The early Greek legends also describe the Elysian Fields which were in another part of the world, away from the sounds of suffering which constantly came out of Tartarus. Here was the abode of the blessed, surrounded by fragrant and beautiful flowers and even provided with a sun and moon of their own.

PRIMITIVE MAN DID NOT UNDERSTAND THE RISING AND SETTING OF HEAVENLY BODIES

From the very earliest time it must have been obvious to those who noticed the risings and settings of the heavenly bodies that either the earth is rotating on its axis or every heavenly body is revolving around the earth. Of course we cannot conceive of all of the millions of stars revolving around the earth and taking the same length of time to make the trip no matter how far away they may be, but this difficulty did not stand in the way of the early peoples.

Of course those who believed that the earth was flat did not take the time to investigate its motion. They knew that it was fixed. But even those who believed that the earth was spherical could hardly convince themselves that it was spinning on its axis like a top.

The Greek philosopher, Aristotle, attempted to account for the rising and setting of the sun, moon and stars by assuming that the heavenly bodies were attached to crystal shells which were rotating around the earth. It is interesting to see to what

extremes men would go to make their ideas about the universe correspond with what they saw in nature.

From classical mythology we learn that Apollo, the sun god, lived with his attendant Aurora, the goddess of dawn, in the palace of the sun in the east and daily drove the sun across the sky in a chariot drawn by fiery steeds. He would give mortal man what heat and light he needed and then quickly return to his eastern home through some subterranean passage so as to be ready for the duties of the following day.

It was the duty of Diana, the twin sister of Apollo, to drive the moon car across the sky so as to furnish a limited amount of light while Apollo was resting from his labors.

Every school boy is now familiar with the fact that the earth is daily rotating on its axis, bringing mankind every morning into the life-giving rays of the sun and arousing him to new activities, and then twelve hours later carrying him around into the shadow of the earth for rest and sleep. However, very few of the wise men among ancient peoples explained this succession of day and night by the rotation of the earth. Believing that the earth was fixed they were forced to invent many crude devices for the purpose of explaining this natural phenomenon.

PTOLEMY SOLVED THE PROBLEM OF RISING AND SETTING OF HEAVENLY BODIES

Several of the early Greek philosophers taught that the earth was round and most of these men also believed that the earth was rotating on its axis. They were, however, in the minority. The great astronomer, Ptolemy, who proposed a very curious scheme of the universe which was taught in the schools for about fifteen centuries, could never convince himself that the earth was moving. He very carefully weighed all of the evidence both for and against the rotation of the earth and, unfortunately, decided in the negative.

Some of the arguments which were very convincing to Ptolemy would not carry much weight today. Unfortunately Ptolemy overlooked the possibility that the atmosphere of the earth might be rotating along with the earth. He argued that the rotation of the earth was impossible because such terrific air currents

would result that everything which was not securely fastened to the surface of the earth would be quickly blown away.

He called attention to the fact that the earth was not swept by this continuous cyclone and consequently there was no rotation. "If it were true," said Ptolemy, "that every point on the surface of the earth is being carried eastward at a speed of several hundred miles per hour by its rotation, then no bird could ever fly toward the east. Just as soon as any winged creature jumped from the limb of a tree, then, no matter how fast it might fly, the tree would be carried eastward more rapidly than the bird and its flight would obviously be toward the west." Ptolemy had actually seen birds fly toward the east and consequently he was satisfied that the earth did not rotate.

If we were inclined to carry this argument further, we might propose a very convenient trip from St. Louis to Denver. Just get in a balloon in St. Louis and rise above the surface of the earth and wait about an hour until the rotation of the earth brings Denver directly beneath you and then come down again. Of course we can see the difficulties in the way of a voyage of this kind, but these difficulties were not evident to Ptolemy.

Consequently he invented his curious celestial machine which, although very complicated, was sufficiently accurate to account for the observed movements of the heavenly bodies. Ptolemy's ideas were adopted by those in power and were taught as truths until long after the discovery of America.

WE CAN ACTUALLY SEE THE EARTH ROTATE BENEATH OUR FEET

From early times educated people have felt sure that the earth was rotating on its axis and have been unwilling to accept the ideas contained in classical mythology which attempted to account for the rising and the setting of the sun, the moon and the other heavenly bodies. They realized that the apparent motion of the stars as seen from an earth rotating inside of a fixed sky would be identical with that observed from a fixed earth inside of a revolving sky. Their problem was to determine whether the earth or the sky was in motion.

The problem of the daily rotation of the earth was not solved to the satisfaction of the leaders of scientific thought until the middle of the nineteenth century. Of course many people were convinced long before that time that the earth was rotating on its axis but it was not until 1851 that the famous Foucault pendulum made it possible for us to watch the earth turn under our feet.

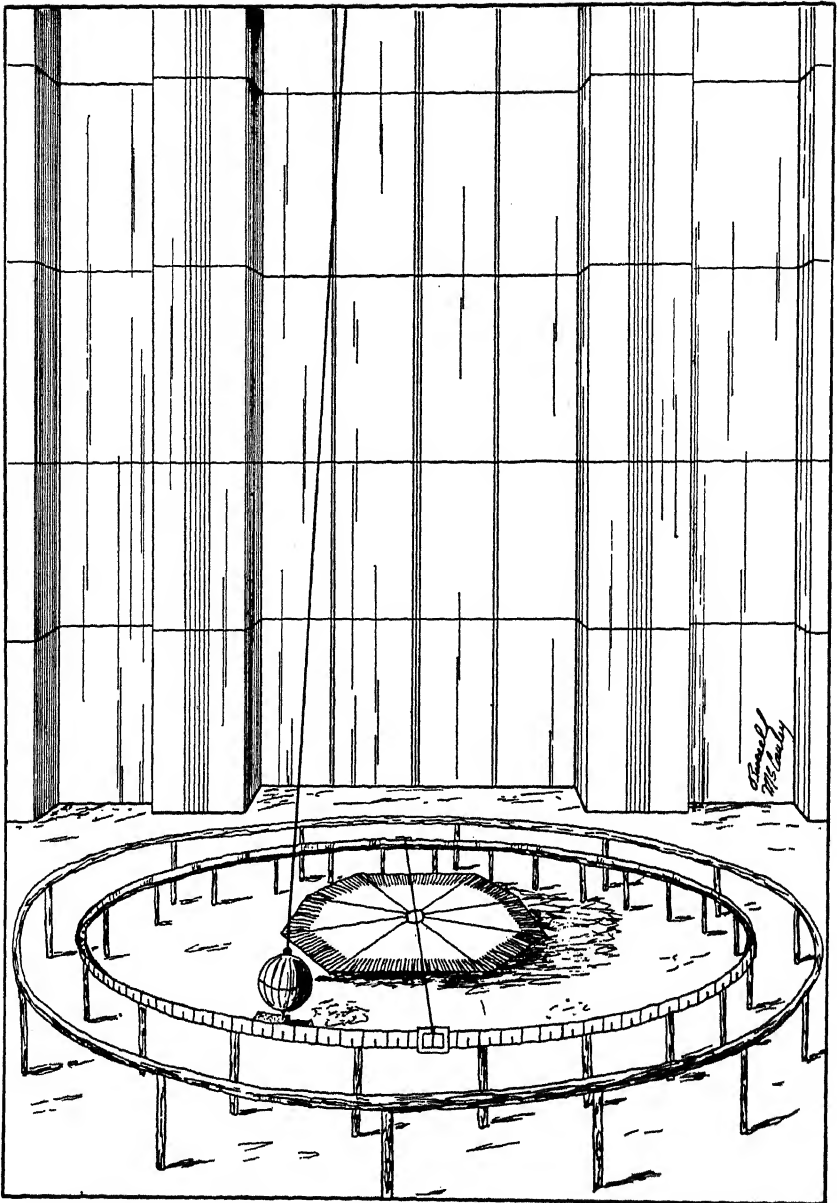
The rate of the rotation of the earth is not constant but its speed seems to be decreasing. However, this decrease is so very slight that the length of our day will not change more than one second in a thousand centuries. In fact, the human brain has not been able to devise any mechanical means for keeping time which can compete with the rotation of the earth on its axis.

Every point on the surface of the earth seems to be moving eastward at a uniform speed which depends upon where the point happens to be located. A person on the equator is carried eastward at the rate of about 1000 miles per hour, another person in latitude 60 degrees is moving 500 miles per hour, while a third person at the north or south pole would not be affected by this rotation, except that he would be turned around once in twenty-four hours.

Of course we are unconscious of the fact that other objects on the earth are continually taking our place in space. The place where we now stand will pass on to the eastward and if it were possible for us to remain suspended in space and watch this rotation, we would see other points on the surface of the earth pass beneath our feet, the wide expanse of the Pacific Ocean requiring only seven hours to pass beneath us.

PRIMITIVE MAN BELIEVED THAT THE EARTH WAS THE CENTER OF THE UNIVERSE

Since primitive man believed that everything in space was created for the benefit of the earth he naturally assumed that the earth was at the exact center of the universe and that the sun, moon and stars were placed in the sky for his benefit and were made to revolve about him. This seems to have been the opinion of the majority of the early Greek philosophers includ-



If a long pendulum be allowed to swing undisturbed for several hours we can actually watch the floor turn beneath our feet. This experiment was first performed by Foucault in 1851.

ing Thales, Aristotle, Plato, and Euclid. From the writings of Cicero and Seneca we learn that this interpretation of the position of the earth in the universe was entirely satisfactory to the Roman people.

The Greek philosopher, Aristotle, whose ideas were held sacred for many generations, taught that the universe was a sphere—the most perfect of all solids—with the earth at the center. Around the earth was an elaborate system of fifty-five concentric hollow spheres so regulated as to completely account for all of the movements of the heavenly bodies.

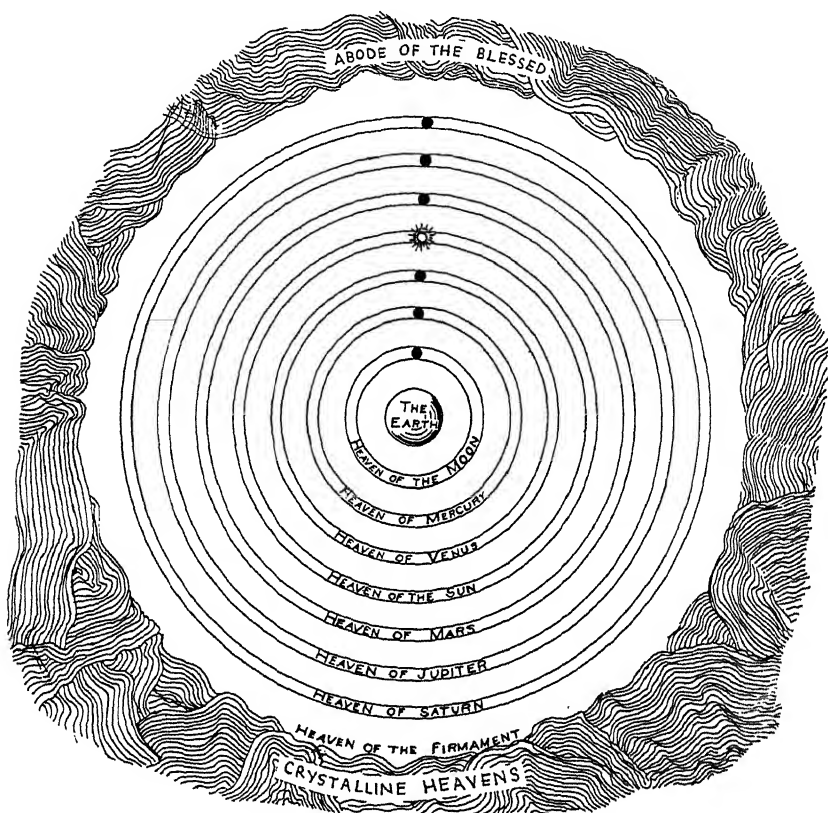
The famous astronomer, Ptolemy, who lived in Alexandria about 140 A. D., was the author of the *Almagest*, made up of thirteen books, which explained his crude ideas. He believed that the earth was a globe in the center of the universe. Revolving about the earth were seven crystal shells, like skins on an onion. These shells—made of glass so that it might be possible to see through them—were called heavens, which explains why literature contains so many references to seven heavens.

Ptolemy's attention was called to the fact that the sun was not in exactly the same position in the sky at the time of the vernal equinox year after year but that it was changing its position at such a rate that it would make a complete circuit of the sky in about 26,000 years. In order to take care of this apparent motion of the sun Ptolemy simply added to his elaborate system of spheres a new motion of the entire sky. After the universal law of gravitation had been given to the world by Newton it was obvious that this movement of the equinoxes was a direct consequence of his law. In other words, not only did the law of gravitation explain the motions of all of the planets and eliminate Ptolemy's elaborate system of spheres but it also took care of the movement of the equinoxes and many other phenomena which were unknown to Ptolemy.

THE SEVEN HEAVENS OF EARLY PEOPLES PRODUCED THE "MUSIC OF THE SPHERES"

Early peoples noticed that the stars did not change their relative positions in the sky so that it was reasonable to suppose

that they were all firmly attached to a hollow sphere. But there were seven heavenly bodies—the sun, the moon, Mercury, Venus, Mars, Jupiter and Saturn—which moved about among the fixed stars and were called “planets” (from a word meaning “wanderers”). In order to account for their motions Ptolemy assumed



Around Ptolemy's primitive earth rotated seven crystalline heavens, to each of which was attached one of the so-called planets.

that one of these bodies was in some way attached to each of the seven heavens and that the heavens themselves were turning about the earth carrying these bodies with them. In order to account for certain irregularities in their motions Ptolemy proposed a system of epicycles which we will not discuss here. Beyond the seventh heaven, which was the heaven of Saturn, was the firmament on which was to be found the fixed stars. All of these stars were supposed to be at about the same distance from the earth.

You may, perhaps, be familiar with the Arabian legend that describes the visit of Mahomet, accompanied by the angel Gabriel, to each of the seven heavens. In the first heaven he was welcomed by Adam and in the second he met Noah. The third heaven was the home of Abraham and in the fourth heaven he found Joseph, the son of Jacob. When he arrived in the fifth heaven he discovered Moses, and in the sixth, John the Baptist. In the seventh heaven, which was the most beautiful of all, he found Christ and near him, upon a throne of gold, sat the Ruler of the universe.

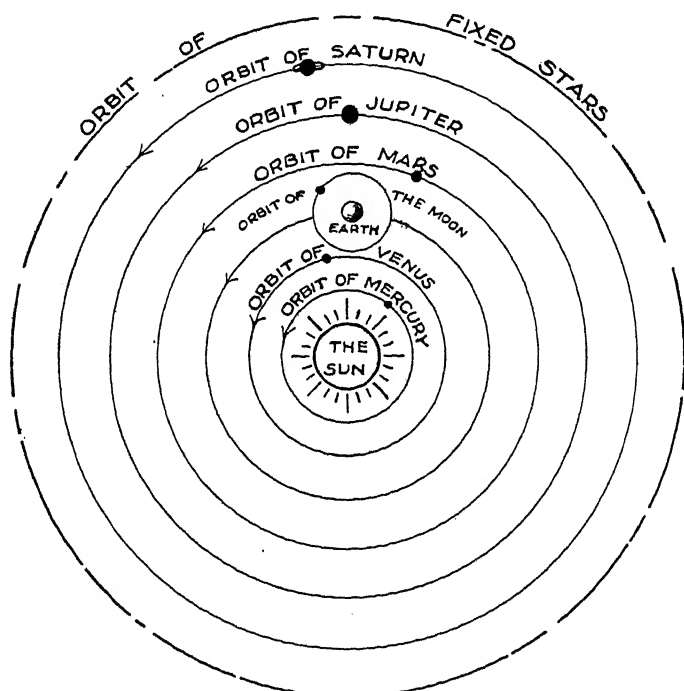
The early poets and philosophers remarked that as the seven different heavens revolved about the earth they gave rise to a vibration in the ether and produced seven different musical notes. Since there are just seven notes in the musical scale they soon began to talk about the "music of the spheres," to which we frequently find reference in the poetry of today. It was useless to argue that there was no such thing as the music of the spheres because no one had ever heard it. How could we expect to hear it, since this music has been in the air ever since the birth of the human race and our ears are accustomed to it? A concert before a deaf audience would be a concert still.

COPERNICUS REVEALED THE POSITION OF THE EARTH IN THE UNIVERSE

In spite of the erroneous teachings of the leading thinkers of ancient times the correct idea with reference to the position of the earth in the universe seems to have been in the minds of a few of the early Greek philosophers. The great mathematician, Pythagoras, who is responsible for the theorem that the square on the hypotenuse of a right triangle is equal to the sum of the squares on the other two sides, taught in the sixth century B. C. that the earth revolved about the sun which was the center of the universe. Aristarchus, in the third century B. C., and Capella, in the fifth century A. D., tried to get the people to see the truth but the odds against them were too great.

It is unfortunate that those who were in a position to impress their ideas upon others insisted upon a literal interpretation of

some of the poetic statements in the Old Testament, and accepted the system of Ptolemy with a slight modification. They rejected the only feature of Ptolemy's scheme that was correct, namely, that the earth was round. According to the teachings of a majority of the leaders of thought for fifteen centuries the earth was flat and at the center of the universe. The great Italian poet Dante in his *Divine Comedy* in the early part of the fourteenth century fixed these ideas so strongly in the minds of most people that there was no question but that everything in the universe revolved about the earth.



THE COPERNICAN SYSTEM

The truth about the position of the earth in the universe remained hidden for more than a thousand years until the great Polish astronomer, Copernicus, in a book published in 1543 A. D., stated that the earth was rotating on its axis and proved that this would account for the rising and setting of the stars and other heavenly bodies. He also taught that the earth was merely one of a number of heavenly bodies which were moving around the sun in circles and he showed that this revolution

would account for the apparent motions of the seven bodies which Ptolemy had called planets. Being afraid to state his system of astronomy as a fact Copernicus proposed it as an hypothesis. He did not dare to publish it until late in his life. In fact it is said that the book did not appear until the day of his death.

THE WORLD WAS WAKING UP AT THE TIME OF COPERNICUS

We are not surprised that man's ideas about his universe began to change about the time of Copernicus, for just at this time the manners, customs, and the very lives of the people were being made over. About fifty years before the death of Copernicus, Columbus had discovered a new world and man's notions about the size and shape of the earth had been radically changed. His own country was no longer the center of the earth, but there were other races of people living across the sea thousands of miles away. Just before the death of Copernicus the art of printing with moveable type was invented by Gutenberg and correct scientific ideas began to spread very rapidly.

While Copernicus was devoting his attention to astronomy, Leonardo da Vinci painted his *Last Supper* and *Mona Lisa*, Michelangelo chiseled his masterpieces out of solid stone, Titian created his celebrated *Assumption of the Virgin* and Raphael gave to the world his *Sistine Madonna*.

The system of astronomy proposed by Copernicus of Poland was not quite correct in some of its minor details but it was soon corrected and revised by Galileo in Italy, Kepler in Germany, and Newton in England, and it finally replaced the system of Ptolemy. However, in some of the oldest American universities the two astronomical systems were taught side by side for some time.

It is sometimes hard for us to understand how difficult it was for people to give up the idea that the earth was the center of the universe. Under the system of astronomy which was outlined by Ptolemy, man was the object of creation and "monarch of all he surveyed." Under the system of Copernicus man was merely an insignificant creature clinging to a small planet which, with

six other planets, was revolving around the central sun. What a loss of dignity! What a gain in grandeur!

How do we know that the earth revolves about the sun? Would not the varying positions of the stars result just as well from the sun revolving about the earth? Yes, but it would be ridiculous to assume that a large body is going around a small body. The sun weighs about 700 times as much as all of the planets combined so that, if there is any revolving to be done, it must be done by the planets and not by the sun.

THE MOTION OF EARTH ABOUT THE SUN CAN BE SEEN IN THE STARS

We are unconscious of the fact that we are moving around the sun, because the earth carries its atmosphere with it, but actual proof of our motion is not difficult to find. Is it not more reasonable to assume that our little earth moves about the sun than that the sun whose mass is 332,000 times that of the earth revolves about us? A study of the positions of the stars also furnishes direct proof that the earth is in motion.

After the invention of the telescope it was discovered that every star in the sky apparently moves around a little orbit every year. This motion of the stars is only apparent and is due to the fact that we are moving around the sun. If the earth were fixed in space the stars would not have this motion.

Early scientists were not aware of this motion of the stars because they had no telescopes. In fact one of the early astronomers used this very argument to prove that the earth was not moving. He stated that, if the earth were moving around the sun, every star would appear to be moving with a period of one year, and since the stars did not have this motion, then the earth was not moving. An excellent argument, but based upon false premises. Of course the stars actually were moving in exactly this manner, but he could not detect it. The invention of the spectroscope during the first half of the nineteenth century made possible certain observations which convinced man that his little world was in motion.

THE EARTH MOVES ALMOST NINETEEN MILES
EVERY SECOND

The earth does not move around the sun in a circle but in an oval-shaped curve, an ellipse, the sun being a short distance out of the center. The earth does not move at a uniform rate. In January we are closer to the sun than at any other time and our motion is "speeded up" in order to avoid being pulled into the sun. In July, when we are farthest away from the sun, we move much more slowly. Our average velocity around the sun is eighteen and one-half miles per second. This is greater than any speed with which we are familiar on the earth, although this motion is rather slow in comparison with the velocities of some of the other heavenly bodies.

If a weight be tied to a string and then be rapidly whirled it will tend to move always in a fixed plane which passes through the center of motion. This is also true of the motion of the earth around the sun. The fixed plane in which the earth is moving in its annual trip about the sun is known as the "ecliptic" and everyone on the earth is obviously living in this plane. If the plane of the ecliptic be extended indefinitely in all directions, it will cut the imaginary Celestial Sphere in a circle which is known as the "ecliptic circle."

Since we do not realize that we are moving and unconsciously assign this motion to the sun, we may define the ecliptic circle as the path among the stars which is traced by the center of the sun during the course of a year. The moon and all of the planets, as viewed from the earth, always lie very near the ecliptic circle. The existence of the ecliptic circle has been recognized since remote antiquity. The Chinese evidently knew about this circle as early as 1100 B. C. and the Greek astronomer, Eratosthenes, referred to it about 200 B. C.

On account of the attraction of the other planets the shape of the earth's orbit and its position in space slowly change, but these changes are periodic so that there seems to be no danger of a collision with other planets or with the sun. The periodic changes in the orbit of the earth seem to have no effect on the length of the longest diameter of the ellipse or on the length of the year. These apparently remain unchanged.

THE EARTH'S ROTATION CAUSES HEAVENLY BODIES TO RISE AND SET

We know that the earth has two distinct motions but neither of them can actually be felt by those who live on its surface. All of the heavenly bodies appear to us to be in motion but these motions are only apparent and are due to the fact that we are living on a flying world. It is interesting to study the effect on the appearance of the sky of the revolution of the earth around the sun and of its rotation on its axis. Suppose we consider the effect of the earth's rotation first.

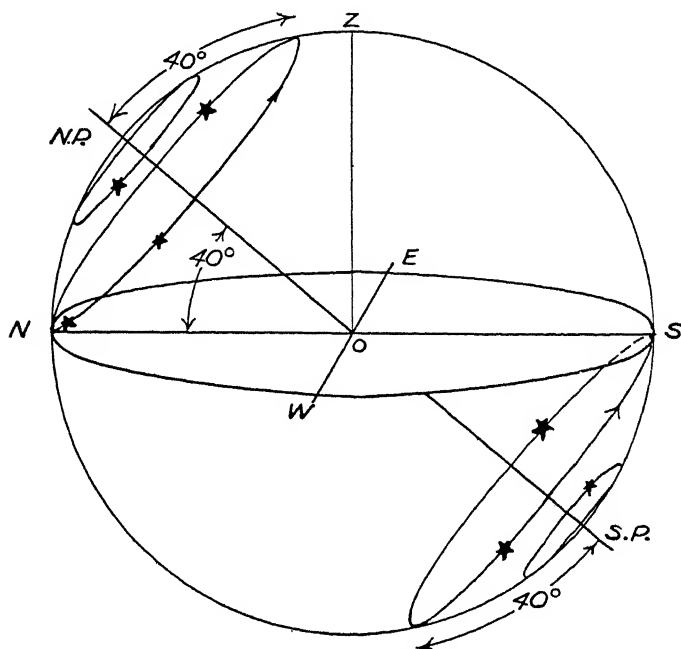
How does the earth's rotation affect the appearance of the sky? From the very beginning men have watched the sun, moon and stars rise in the east, move slowly across the sky and set in the west. This motion is of course due to the earth's rotation from west to east. If the earth's imaginary axis of rotation be produced indefinitely it will strike the sky at two points called the "celestial poles." The North Celestial Pole is very close to the star Polaris. It is for this reason that this star is called the North Star.

All heavenly bodies appear to move from east to west around the North Star always remaining at a constant distance from that star. Certain constellations which are not too far from the North Star are always visible to those who live in the northern hemisphere. The most interesting of these is perhaps the Big Dipper which goes round and round the North Star, never going below the ground. In fact it is by means of the Big Dipper that the North Star is usually identified.

The apparent motion of the stars around the North Celestial Pole may be exhibited very clearly by means of photography. Suppose we choose a location far removed from artificial lights and mount our camera in such a way that it will point directly at the North Star. If the plate be exposed for several hours the picture will show a number of circular trails, each one being produced by a star as it moves around the pole. Let us now take another photograph with the camera pointed at Orion, or at any group of stars mid-way between the two poles. When we examine this picture we will be surprised to find that the star trails are not circles but straight lines,

THE NORTH STAR GUIDED EARLY NAVIGATORS ACROSS THE SEA

It is a fundamental law of nature that the altitude of the North Celestial Pole above the northern horizon is always the same as the latitude of the person who is making the observation, so that if you are living in latitude forty degrees north the North Star will always be forty degrees high. As a result of this fact



If you live in latitude 40°N , the North Star is 40° high and no star within 40° of this one even goes below your horizon.

there are many stars that never set and there are many others that never rise. For example, if you are living in latitude forty degrees north then every star within forty degrees of the North Celestial Pole will remain above the horizon all of the time, moving slowly around the North Star. All stars within forty degrees of the south pole will remain below the horizon at all times and will never be visible to you unless you move toward the south. All stars between these two extremes will be above your horizon at some time during the day or night.

The fact that the altitude of the North Star is always the same as the latitude of the observer is very important in navigation. Before this secret of nature was found out sailors had no way of knowing where they were if they happened to get out of sight of land. Navigators get across the ocean simply by knowing their latitude and longitude at frequent intervals. Of course other sciences have contributed to the development of navigation, but it is mainly astronomy that has made the ocean safe.

Navigators in early times had no idea how far they were east or west of a given point and even after they learned how to tell their latitude from the altitude of the pole star they were perfectly helpless in cloudy weather.

The compass came into general use in the fifteenth century in spite of the opposition of those in power who claimed that this interesting little instrument was the work of the devil. There now resulted a period of progress in navigation which resulted in the discovery of America. The calculations of the navigators were still somewhat crude because they had not learned that the compass needle does not point to the north pole of the earth, but to the north magnetic pole which changes from year to year. The astronomer Halley of cometary fame constructed the first compass variation chart in 1699 and this difficulty was to a certain extent eliminated.

RADIO NOW MAKES NAVIGATION SAFE

Up to the eighteenth century ships were being navigated without any knowledge of longitude. If a ship were sailing west the navigator would try to get on the parallel of latitude which passed through his destination—by making daily observations on the North Star—and then continue westward until he came within sight of land. During the seventeenth century much time and energy were devoted to the solution of the longitude problem and the Royal Observatory of England was established in 1675 for this purpose. It was recognized that the navigator could accurately determine his longitude only by knowing the difference between his time and the time at some given point on the shore at the same instant. It was very easy to determine the

local time at the Royal Observatory by making certain observations on the stars and if the navigator had any way of knowing what this time was his problem would be solved.

In 1735 the chronometer was invented by Harrison and most of the difficulties of the navigator vanished. Before leaving shore the chronometer, which is merely a very accurate clock, was carefully regulated to carry correct observatory time. If the captain of the ship wished to know his longitude he would merely calculate his local time from the stars or from the sun and then glance at the chronometer which is carrying observatory time. If his local time is one hour slower than the chronometer he is fifteen degrees west of the Observatory.

Every school boy knows that the difference in local time between two points on the earth is one hour for every fifteen degrees of longitude, but very few people can answer the question as to why our modern maps are drawn in such a way as to show the longitude from Greenwich and not from London. Why has this suburb of London been selected as a starting point for measuring longitude? The answer is obvious. Longitude is measured from the meridian which passes through the transit instrument in the Royal Observatory in England and this Observatory is located at Greenwich.

For more than one hundred and fifty years ships were sailed by means of the chronometer which was gradually improved until it was, for practical purposes, absolutely accurate. The invention of the radio has made it possible to send out hourly time signals from powerful broadcasting stations so that the chronometer has now lost its importance. And so the world moves on.

THERE ARE THREE IMPORTANT CIRCLES IN THE SKY

We have seen that the axis of the earth, when produced indefinitely in both directions, pierces the sky in two important points—the North Celestial Pole and the South Celestial Pole. Another important point in the sky is the Zenith, which is always directly overhead. This is the point where a plumb line would pierce the sky if extended indefinitely. These three points in the

sky—the two poles and the Zenith—determine a circle which is known as the Meridian. Every heavenly body crosses the Meridian once every day.

There is a great circle on the earth known as the Equator, which lies halfway between the two terrestrial poles. If the plane of the earth's equator be produced indefinitely in all directions it will intersect the sky in a great circle which is known as the Celestial Equator. This great circle will of course be just halfway between the North Celestial Pole and the South Celestial Pole, being just ninety degrees from each.

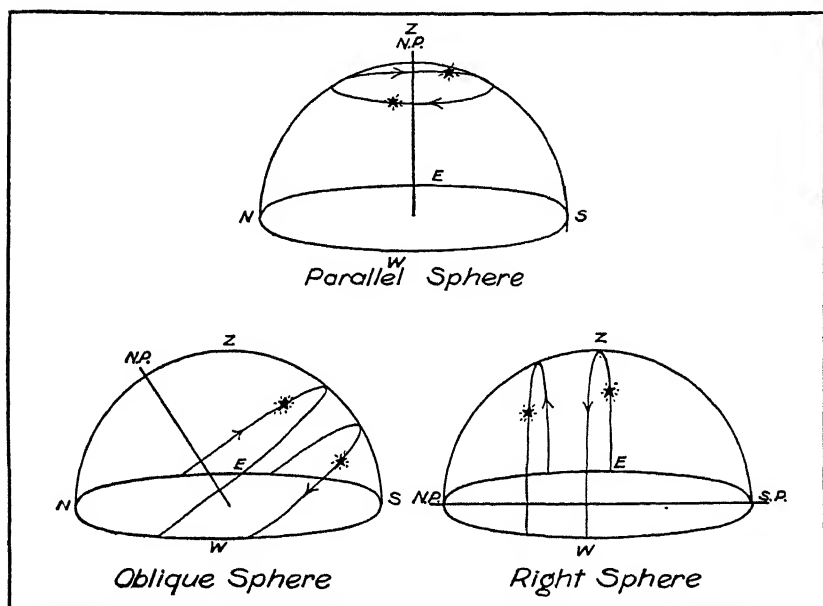
The Celestial Equator always cuts the horizon in the east and west points and the approximate position of this imaginary circle in the sky may be determined if we can tell how far south of the Zenith it crosses the Meridian. This may be easily determined for any latitude, if we remember that the altitude of the North Star is always the same as the latitude of the observer. If you are living in latitude forty degrees north, then the North Star is forty degrees above the northern horizon and the Celestial Equator crosses the Meridian forty degrees south of the Zenith, since it is always ninety degrees from the North Celestial Pole.

The third imaginary circle in the sky—the annual path of the sun among the stars—is known as the Ecliptic. Although these three circles are thoroughly understood and are used daily by the astronomer they are sometimes a little mysterious to the layman. We hope, however, that the average person will not make the same mistake as the geography pupil, without a textbook, who heard his teacher define the equator as an imaginary line that encircles the earth and then wrote on his examination paper, "The equator is a menagerie lion running around the world."

THE MOVEMENTS OF STARS DEPEND UPON OUR LATITUDE

Since the axis of rotation of the earth pierces the sky in two points, known as the north and south celestial poles, the sun, moon and stars will appear to move around these points from east to west as the earth rotates from west to east.

Let us suppose that we are living in the northern hemisphere and that our latitude is forty degrees. Then the North Star, which is very close to the north celestial pole, is approximately forty degrees high and all heavenly bodies will appear to move in circles around this star. Let us now watch a star that is just rising on the eastern horizon. Since this star must move in a circle whose plane is perpendicular to the axis of the earth, it will start out at



For observers at the North Pole all heavenly bodies move in circles parallel to the horizon. Those on the earth's equator see these bodies move in circles perpendicular to the horizon, the North Star being at the northern point of the horizon.

an angle of fifty degrees with the horizon and travel in a direction which slopes toward the south until it reaches the meridian, at which time it starts toward the north. We have all noticed that the sun moves in this way and also the moon, but we may perhaps not be aware of the fact that the stars also have a similar motion.

If we should move to the equator the North Star would gradually sink down to the northern horizon and every heavenly body would go straight across the sky after rising on the eastern horizon, without veering toward the north or south. It would

remain above the horizon exactly twelve hours and then would be below the horizon for the same length of time.

If we should then continue our journey into the southern hemisphere the north pole would sink below the northern horizon and the south pole—which is not marked by any conspicuous star—would come above the southern horizon a distance equal to our latitude. All heavenly bodies would then move toward the north, instead of the south, as they climb up into the sky and the sun at noon would be north of the zenith instead of south.

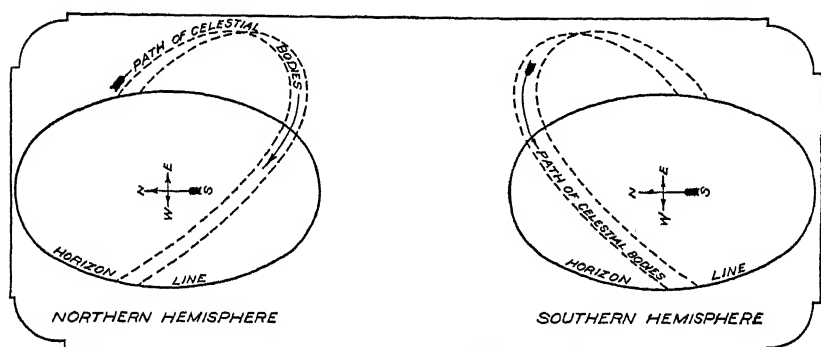
If we should take up our position at either the north pole, or the south pole, of the earth, we would find the north (or south) celestial pole exactly at the zenith and all visible heavenly bodies would move around this point in circles parallel to the horizon. In other words, no star would ever set and those stars which were below the horizon would never rise.

PEOPLE IN SOUTHERN HEMISPHERE SEE SUN AND MOON IN NORTH

Those of us who have always lived in the northern hemisphere sometimes find it rather difficult to picture in our minds the positions and movements of the heavenly bodies as seen from the southern hemisphere. We are accustomed to seeing the sun and the moon drift toward the south as they climb the eastern sky, cross the Meridian south of the Zenith and then drift toward the north as they approach the western horizon. But people living south of the equator see them drift first toward the north and then toward the south, crossing the Meridian north of the Zenith. Not only the Man in the Moon but also the sun itself appears upside down when looked at from across the equator.

Let us consider the behavior of the sun on the 21st of June as seen from the United States and from South Africa. We see the sun rise north of east and set north of west after describing its longest arc of the year. The Africans watch it rise north of east and set north of west after describing a very short arc toward the north. Thus when we have our long days they have their short days and nature has so arranged things that the seasons in the two hemispheres are exactly opposite.

When we face the direction of the noonday sun we are looking toward the south, east is on our left and west is on our right, and all heavenly bodies are moving from east to west which is from left to right. If we should move to South Africa and face the noonday sun we would be looking toward the north. All heavenly bodies would still move from east to west, but this motion would be from right to left and not from left to right. We have no right to say that one of these motions is forward and the other backward, because they are both fixed by nature and are perfectly normal to those who are accustomed to observing them.



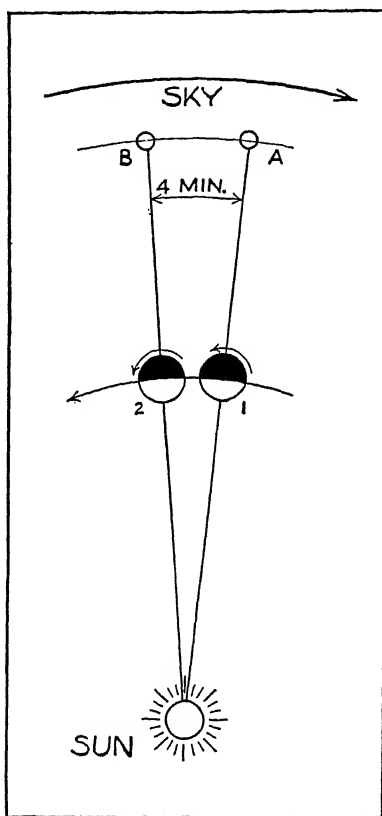
As the sun, moon, and stars mount the eastern sky we see them move toward the south, but our neighbors in the southern hemisphere see them move toward the north.

Certain Phoenician sailors claimed to have circumnavigated Africa about 600 B. C. Herodotus, the historian, rejected their claim because "on their return they declared that in sailing around Libya (Africa) they had the sun upon their right hand." In other words, as they sailed westward, they found the sun in the north, that is to their right. To modern people their statement is excellent evidence of the accomplishment of the feat.

EVERY STAR RISES ABOUT FOUR MINUTES EARLIER EVERY DAY

The rising and setting of the sun, moon and stars is a result of the earth's rotation on its axis. This apparent daily motion of the heavenly bodies is very simple and easy to understand when

we realize that we are living on a rotating world, and the curious mechanical devices invented for the purpose of explaining this motion by primitive man, who lived on a stationary world, were discarded years ago. The heavenly bodies also have another



If the star A is on the meridian at midnight tonight, it will be four minutes past the meridian at midnight tomorrow night, because the earth will have shifted its position from 1 to 2.

apparent motion which is not so easily detected as their rising and setting and which is due to another motion of the earth—its annual journey around the sun.

How does the earth's revolution around the sun affect the appearance of the sky? As the earth swings majestically about

the sun it is held in perfect control by the invisible force of gravitation. We need no expensive highway that must be constantly repaired in order that the trip may be made in comfort. Nature sends us through space so smoothly—without a jar or a rattle—that we are unconscious of our motion and we imagine that the sun makes a complete circuit among the stars every year.

Again, let us suppose the earth is in the position 1 at mid-night tonight, with the star A on the meridian exactly opposite the sun. By the time midnight again occurs the earth will have moved eastward to the position 2 and the star B will be on the meridian, the star A having crossed the meridian four minutes ahead of B.

As a result of this apparent shift of the position of the sun, every star rises about four minutes earlier (by the solar clock) every day so that, if a certain star rises tonight at eight o'clock it will rise about seven o'clock two weeks from tonight and a month from tonight it will rise about six o'clock. This apparent drifting of the stars toward the west is responsible for the fact that in the summer Orion and the other beautiful constellations that adorn the winter sky are entirely absent. They are hidden from our view by the glare of the sun. This was of course noticed by early peoples who made many crude attempts to explain why the stars should shift in this manner.

POLARIS WILL NOT ALWAYS BE THE NORTH STAR

As the earth revolves around the sun it keeps its axis parallel to itself all of the time. In other words, it goes around the sun with its axis constantly pointing in a direction which makes an angle of sixty-six and one-half degrees with the plane in which it is moving. This is the thing that is responsible for the seasons—spring, summer, autumn, winter. The apparent motion of the sun toward the north in the summer and toward the south in the winter is a result of the fact that nature has set the axis of the earth at this constant angle.

The sun rises due east about March 21 and then on each succeeding morning it will rise farther and farther north until about the twenty-first of June when it begins to drift back toward the

south, passing the east point on September 22 and reaching its farthest point south about December 21, after which it starts back toward the north, reaching the east point again about March 21. If the axis of the earth were perpendicular to the plane of its orbit the sun would not have this apparent motion and there would be no seasons.

The statement that the earth's axis remains parallel to itself—like many other general statements in astronomy—is not strictly true. The earth is not exactly a sphere and the attraction of the moon and the sun upon its equatorial bulge tends to pull the earth down so that its axis will be perpendicular to its orbit. This result would be accomplished and we would have no more seasons were the earth not rotating.

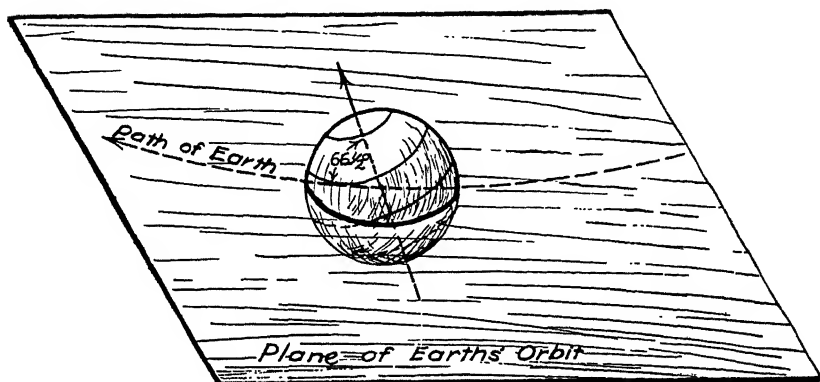
As a result of the conflict between these two natural forces the earth's axis is revolving slowly around a line perpendicular to the plane of its orbit, with which it makes a constant angle of twenty-three and one-half degrees. Consequently, the north pole of the heavens, where the axis of rotation pierces the sky, moves among the stars in a circle with a radius of twenty-three and one-half degrees, making one complete circuit every 26,000 years. The north celestial pole is now passing very close to the star Polaris and this star has the distinction of being the North Star. However, this honor must be shared in time with other stars, one of which is the bright star Vega, which will be the North Star in about 12,000 years.

THE CONSTANT INCLINATION OF THE EARTH'S AXIS CAUSES THE SEASONS

We sometimes say that nature gave us night and day by turning the earth on its axis, and furnished us the succession of seasons by setting the earth in motion about the sun. The last part of this statement is not quite complete for our revolution about the sun would not result in the seasonal variations in the temperature of the surface of the earth, had nature not arranged for the earth to keep its axis always pointed in the same direction.

Let us now see how the constant inclination of the earth's axis causes the seasons. For those of us who live in the northern

hemisphere, the sun and other heavenly bodies rise in the east and move off in a direction that slopes toward the south. Consequently, if they rise north of the east point of the horizon they will obviously be above the horizon longer than they are below. From March 21 to September 22, because of the constant inclination of the earth's axis, the sun rises north of the east point and the days are longer than the nights. Again, from September 22 to March 21 the sun rises south of the east point and is above



The fact that the earth's axis remains fixed in direction as the earth swings around the sun causes the seasons. The size of this constant angle ($66\frac{1}{2}^{\circ}$) determines the width of our five zones.

the horizon for a shorter period than below. Thus the days are shorter than the nights. For those who live in the southern hemisphere the motion of the sun after rising will be toward the north and these conditions will be reversed, the long days coming between September and March and the short days between March and September.

At the equator the sun goes straight across the sky without sloping either way and every day is exactly twelve hours long, so there are no seasons. At the north pole the sun is visible from March 21 to September 22. It rolls around the horizon and gradually climbs to a maximum height of twenty-three and one-half degrees which it reaches on June 21; it then descends gradually until it disappears, to shine on the south pole during the remainder of the year.

A bright high school boy, who knew his physics but not his astronomy, was once asked to explain the effect of heat and cold on material such as iron and steel. He replied, "Heat causes

matter to expand and cold causes it to contract. For example, in the summer it is hot and the days get long, but in the winter it is cold and the days get short."

OUR SEASONS ARE NOT DUE TO VARYING DISTANCE FROM THE SUN

Copernicus in 1543 presented to the world a picture of the solar system that was almost exactly opposite to what man had for centuries taken for granted. He argued that the earth was not at the center of everything but that all of the planets, including the earth, were moving in circles around the sun. This was a correct picture except in one minor detail which was soon corrected. Before many years Kepler guessed, and Newton proved, that the planets were not moving in circles but in oval curves, with the sun somewhat out of the center of each.

Since the orbit of the earth is not a circle, our distance from the sun varies slightly, the sun being 91.5 million miles from us in January and 94.5 million miles away in July. This slight variation in the sun's distance has no effect on the seasons for we usually have our coldest weather in the northern hemisphere in January when we are closest to the sun. When the sun is high in the sky, as it is during the summer, it gives more heat per unit area than when it is not so high. Again, during that same season of the year the days are longer than the nights, so that the amount of heat which is radiated from the earth at night is less than that which is received from the sun during the day. Consequently, the temperature of our part of the earth is much higher in the summer than in the winter.

It seems that nature, when regulating the velocity of the earth around the sun, had in mind the possible effect upon the seasons of the slightly varying distance of the earth from the sun. A study of our calendar will disclose the fact that there are only 179 days between the passage of the sun through the Autumnal Equinox in September and through the Vernal Equinox in March, while there are 186 days between March 21 and September 22. Consequently, although the people in the southern hemisphere have their summer at the time when the earth is closest

to the sun, the southern summer is seven days shorter than the northern summer. On the other hand the people in the southern hemisphere have their winter season when the earth is farthest from the sun and their winter is seven days longer than ours.

PLUTO KIDNAPPED PROSERPINA AND VEGETATION DISAPPEARED

By making use of modern scientific discoveries it is an easy matter for us to explain our variations in temperature. To the minds of primitive peoples, however, the matter was by no means so simple, because of their ignorance of the fact that the earth was moving. They could see no way to bring the flowers and vegetation back to the earth every six months except by some supernatural means. They, therefore, invented the legend of Ceres and Proserpina to explain the succession of the seasons—spring, summer, autumn and winter.

Ceres was the daughter of Saturn, the God of Time, and was the goddess of agriculture and civilization. Her assistant was her daughter, Proserpina, the goddess of vegetation. Ceres and Proserpina lived on the island of Sicily but they spent most of their time wandering about over the country looking after their duties in connection with agriculture. This was very important for if they did not attend to their daily duties the flowers would not be refreshed by the rain, the fields would be completely dried up and the grain would be parched.

One day the beautiful Proserpina and her companions were gathering flowers on the slopes of Mount Aetna when she was discovered by Pluto, the god who presided over the lower regions inside of the earth. Pluto stopped his chariot which was drawn by four coal-black steeds and determined to kidnap Proserpina, for he knew very well that he could not persuade any goddess to share his throne on the inside of the earth where the sun never shone, the birds never sang, and the flowers never bloomed. Before Proserpina was aware of his presence he caught her in his arms and in spite of her prayers and struggles, carried her away to his chariot. He then drove to the lower regions with the speed of a whirlwind.

When Ceres returned home that evening she, of course, missed Proserpina. She immediately began to search for her and wandered about all over the island calling her by name. Day and night she looked for her child but of course her efforts were unsuccessful. She was forced to neglect her duties as goddess of agriculture and famine threatened to visit the people. They called to Ceres in vain for aid but she vowed that nothing on the earth should grow so long as her daughter was detained in Hades.

PROSERPINA'S PERIODIC RETURN FROM HADES CAUSED THE SEASONS

So great was the grief of Ceres at the loss of her daughter that the people became convinced that they could never expect to again see the grass grow or hear the birds sing until they found some way to force Pluto to restore Proserpina to her mother. In despair they appealed to Jupiter, the all-powerful king of the gods, to release Proserpina from the dark regions under the earth and allow her to come back to the upper world once more. Although the commands of Jupiter must be obeyed by the gods as well as by mortals, he preferred not to exercise his authority over so powerful a god as Pluto unless it was absolutely necessary. However, the cries of the starving people from all parts of the earth became so loud that he finally consented to allow Proserpina to return, but only on one condition. She must not have eaten any food during the whole time she had been living in the Infernal Regions.

Ceres was delighted when she was told that she might go to Hades herself and bring her daughter back. However, just as she was ready to start for the upper world, Proserpina was accused of having eaten six pomegranate seeds. When she did not deny this charge Jupiter decreed that for every seed she had eaten she should spend one month of every year in Hades. Consequently, although Ceres was allowed to take her daughter home with her, she could remain on the earth only a short time for it was necessary for her to go back to Hades and spend six months of every year.

Mercury, who was the messenger of the gods, acted as the

escort of Proserpina on these semi-annual trips to and from Hades. Whenever he brought her out of the Infernal Regions the sky became blue and sunny, the grass and vegetation came up out of the ground and flowers bloomed along her way. But, when the six months were over and she again returned to her cave, all nature mourned Proserpina's departure.

The legend of Ceres and Proserpina is just another example of the way in which ancient peoples attempted to explain natural phenomena by supernatural means. The legend of Venus and Adonis is another of this type. Many classical legends were invented for the purpose of explaining phenomena that are merely the results of the operation of natural laws.

THE SUN'S RAYS DO NOT AFFECT TEMPERATURE OF INSIDE OF EARTH

When we speak of seasonal variations in the temperature of the earth we are, of course, referring to its surface and not to its interior. Recent investigations have shown that the heat from the sun does not penetrate more than 100 feet into the earth. At that depth we find a constant temperature of fifty-five degrees which seems to remain unchanged throughout the year, no matter whether located in the torrid zone or near the poles, and quite independent of the season of the year. From Mammoth Spring flows a stream of water estimated at six hundred thousand gallons per minute at a constant temperature of fifty-five degrees summer and winter.

That the interior of the earth is very hot is evident from the study of volcanoes, geysers and earthquakes, and geologists tell us that near its surface its heat increases about one degree Fahrenheit for every seventy-five feet in depth. If the temperature increases at a uniform rate its value at a depth of one mile is one hundred and twenty-four degrees Fahrenheit, and if a layer of the earth a little more than two miles thick should be peeled off its entire surface would have the temperature of boiling water. If we could get down several hundred miles below the surface we would probably find a temperature almost as great as that which existed when our world was born.

Where did the earth get this enormous quantity of heat? Although many theories have recently been proposed it must be admitted that this question has by no means been answered. According to one of the earlier theories as to the origin of the earth, our planet was originally gaseous, and intensely hot. Its surface gradually solidified leaving the enormously hot gases on the inside of a solid crust. If this is true the earth must be gradually cooling off, since it continually radiates heat into space.

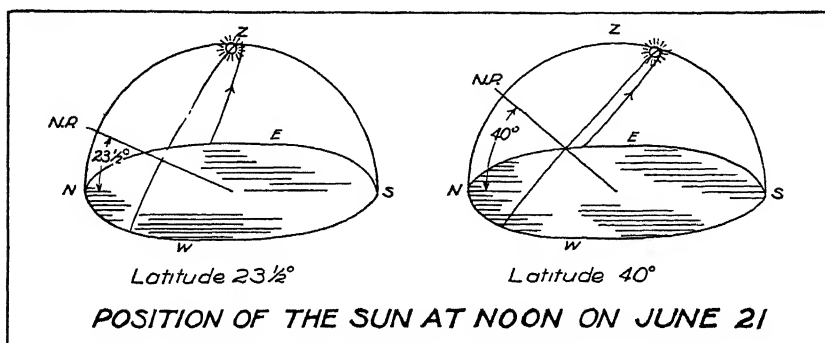
It has been suggested that the earth may have been formed by picking up through the ages countless millions of small bodies such as meteors—at least ten million meteors fall on the earth every year—and that its contraction under this enormous pressure is responsible for the temperature of its interior. Our recent study of the atom has made us appreciate the enormous amount of energy contained in radium and some of the other elements. Who can say that some of this energy is not radiated in the form of heat far below the surface of the earth?

VERY FEW PEOPLE SEE THE SUN IN THE ZENITH

You may recall that when you studied geography you learned that the surface of the earth was divided into five zones—the torrid zone, the north and south frigid zones, and the north and south temperate zones. Perhaps you thought these zones were drawn on the map by the author for our convenience just as we divide a state into counties or as we divide the earth into standard time belts. We can change the county lines or the lines separating the time belts to suit our convenience but the zones, like the length of our day and of our year, are fixed by nature and man can in no way alter them.

Let us see if nature does not have something to do with determining the width of the Torrid Zone. On the longest day of the year in the northern hemisphere (June 21) the sun is just sixty-six and one-half degrees from the north pole, and for an observer living in latitude twenty-three and one-half degrees north, the sun will be in the Zenith at noon. Likewise on the longest day of the year in the southern hemisphere (December 21) the sun will be exactly sixty-six and one-half degrees from

the south pole and those who live in latitude twenty-three and one-half degrees south will have the sun directly overhead at noon. Those who happen to live between these two parallels of latitude will have the sun in the Zenith at noon twice each year—once when it is going north and again on its return to the south—and none of the rest of us will ever see the sun in that position. It is, therefore, natural to call that belt which extends



twenty-three and one-half degrees north and south of the equator the "Torrid Zone," since we would expect this to be the hottest part of the earth.

The Torrid Zone is bounded on the north by an imaginary circle known as the Tropic of Cancer and on the south by another imaginary circle which we call the Tropic of Capricorn. The origin of these names is obvious when we recall that the sun, as it makes its annual journey through the twelve signs of the Zodiac, is always in the sign of Cancer when it gets twenty-three and one-half degrees north of the Celestial Equator and in the sign of Capricornus when twenty-three and one-half degrees south of the Equator.

THE HAND OF NATURE LAID OUT OUR TERRESTRIAL ZONES

Not only has nature set the earth in motion around the sun in order that man might have the year as a convenient unit of time, but she has also tilted the axis of the earth at a constant angle so that he might enjoy a variation of seasons throughout

the year. The size of this angle determines the amount of the variation in our surface temperature and maps out five different zones on the earth.

On June 21 the northern hemisphere is tipped toward the sun by its maximum amount so that the sun's rays extend twenty-three and one-half degrees beyond the north pole and those who live within twenty-three and one-half degrees of the pole are able to see the sun for twenty-four or more consecutive hours. This fixes the location of the arctic circle within which lies the land of the "midnight sun." The same situation exists at the south pole on December 21 while the north polar regions are frozen solid because of the absence of sunlight. It is, therefore, convenient to think of the Frigid Zones as extending twenty-three and one-half degrees from each of the two poles.

The Torrid Zone extends twenty-three and one-half degrees on each side of the earth's equator. Only on this part of the earth will a person ever find the sun in his Zenith. The North and South Temperate Zones are defined as the remaining area of the earth lying between the two Frigid Zones and the Torrid Zone. It is on this part of the earth that most of its inhabitants live.

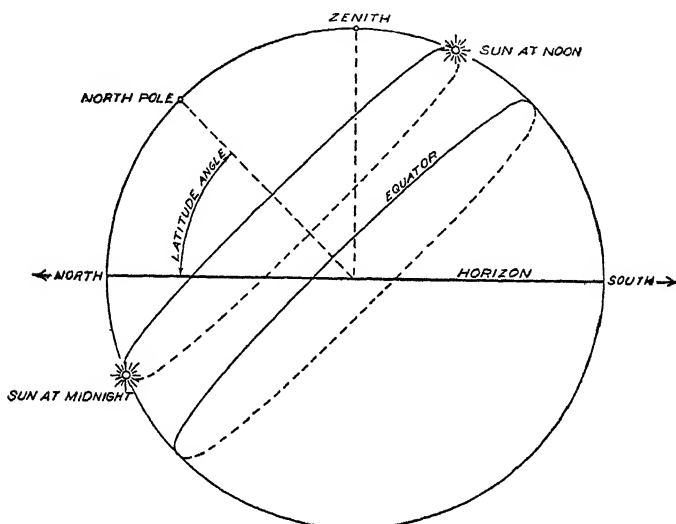
Thus the lines that separate our five zones are drawn on the surface of the earth by the guiding hand of nature, the location of these lines being determined by the fact that the axis of the earth makes an angle of sixty-six and one-half degrees with the plane of its orbit. If something should change this angle the width of our zones would be changed. If this angle should be changed to forty-five degrees our Temperate Zones would disappear. The Frigid Zones would extend from the two poles a distance of forty-five degrees toward the equator and the belt between these two zones would be entirely taken up by the Torrid Zone.

THE SUN IS IN THE NORTH AT MIDNIGHT— NOT STRAIGHT DOWN

Where is the sun at midnight? If you ask this question of the average person he will point straight down. Try it on one of your

friends and see. This is correct only for people in the Torrid Zone and on only one or two nights in the year.

Suppose we are in the North Temperate Zone and we are asked this question on June 21 when the sun is sixty-six and one-half degrees from the North Star. The sun will rise at some point north of east and start across the sky. Its path will slope toward the south until noon, then toward the north and when it sets



The sun is at the same distance from the North Celestial Pole at noon and at midnight.

in the northwest it is still going north. In other words, the sun will dip down below the horizon in the northwest, pass on to the east under the North Star (north pole) and then come up again in the northeast. If we are far enough north of the equator the sun may not go deep enough below the northern horizon for it to become completely dark.

Twilight is caused by the reflection of sunlight from the upper portion of the earth's atmosphere, and ends when the sun gets eighteen degrees below the horizon. At the equator the sun goes straight down after setting and sinks below the horizon at the rate of about fifteen degrees per hour so that twilight in the tropics lasts only about seventy-two minutes. As the observer moves north from the equator the sun rises and sets at an angle with the horizon which decreases as the observer's latitude increases. Thus the higher the latitude the more time is required

for the sun to sink below the twilight line and the length of twilight (and dawn) is increased. In fact at all points north of latitude forty-eight and one-half degrees and south of the arctic circle twilight will last all night on June 21, for the sun will not get more than eighteen degrees below the horizon as it swings under the Celestial Pole. Inside the arctic circle the sun will not set at all.

If we wish to point at the sun at midnight on June 21 we should point due north just sixty-six and one-half degrees under the North Star, for in the summer time in the North Temperate Zone the sun is in the north at midnight and not straight down.

SUMMER DAYS ARE LONGER IN THE NORTH THAN IN THE SOUTH

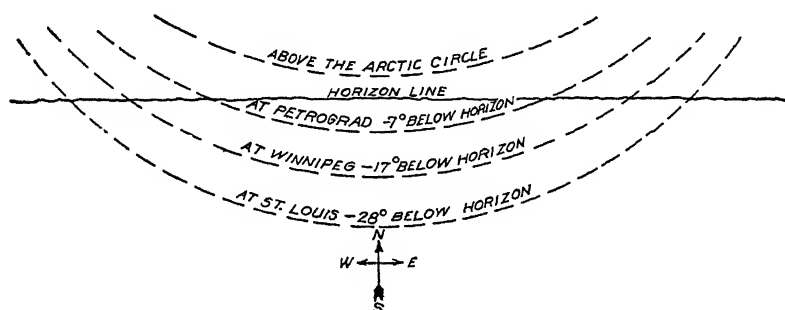
Everyone who has traveled very extensively has noticed that in the summer time the days are longer in the north than they are in the south. This is obvious when we recall the fact that on any given day the sun is at approximately the same distance from the North Star at noon and at midnight, and that as we travel north the North Star climbs higher in the sky, lifting the midnight sun up closer under the northern horizon.

Suppose we are in St. Louis (latitude thirty-eight and one-half degrees) on June 21. The sun will be sixty-six and one-half degrees from the North Star which will be found thirty-eight and one-half degrees above the northern horizon. The sun will rise about sixty degrees east of north and set about sixty degrees west of north and then dip down below the northern horizon for a few hours, going to a maximum depth of about twenty-eight degrees; that is, sixty-six and one-half less thirty-eight and one-half degrees.

In Winnipeg (latitude forty-nine and one-half degrees) the sun will rise about fifty degrees east of north and set at the same distance west of north and, since the North Star is forty-nine and one-half degrees high, the midnight sun will be only seventeen degrees below the northern horizon and the night will be much shorter than in St. Louis.

In Petrograd (latitude sixty degrees) the North Star will be

sixty degrees high and the sun will set only thirty-five degrees west of north and will then come back up not very far from the place where it went down, merely dipping about seven degrees below the northern horizon. In fact, since twilight does not end until the sun gets eighteen degrees below the horizon, the sun will not go down deep enough at Petrograd for it to get completely dark at any time during the night. Of course what we are here calling "night" may perhaps last only a few hours.



Sometimes the sun disappears below the northern horizon at night and sometimes it does not, depending upon the latitude of the observer.

Finally, let us suppose that we are spending the summer at any point north of the arctic circle. Then the North Star will be more than sixty-six and one-half degrees high so that the sun will be above the horizon all night. We are here in the land of the "midnight sun."

THE EARTH IS SURROUNDED BY A SHELL OF AIR

About three-fourths of the surface of the earth is covered with water in which many varieties of plant and animal life have developed through thousands of centuries until they have become so accustomed to their native environment that they cannot live on dry land. In like manner there has developed on land the highest type of animal—known as the human race—which is living at the bottom of a sea of air called the "atmosphere." Although we cannot see the atmosphere we realize that we cannot get along without it, for death always results when the air is excluded from our lungs for just a few minutes.

Since the atmosphere is invisible we do not usually think of it as a part of the earth. In fact, the celebrated astronomer Ptolemy of Alexandria, who never dreamed of the existence of the force of gravitation, refused to believe that the earth was rotating on its axis because he could not understand how it could carry the air with it. He was willing to admit that it might be possible for the oceans to rotate with the earth, but he felt sure that the atmosphere would be left behind, so that terrific air currents would be formed which would blow people off of the earth.

This invisible shell of air, which completely surrounds the earth and extends several hundred miles above our heads, has not yet been completely explored by man. Of course we know something about its lowest layer which lies next to the surface of the earth, but the air becomes thinner as we get farther from the earth so that the study of the atmosphere at high altitudes presents many difficulties.

It may truly be said that man is a creature of his environment. Having developed for countless generations on the bottom of the sea of air he must be content to remain where he is. Only by taking oxygen with him can he venture even a short distance from the earth's surface. It is for this reason that the upper regions of our atmosphere are as yet unexplored. A Swiss professor recently went up in a balloon to a distance of ten miles. This was quite an accomplishment, but he penetrated the atmosphere a distance of not more than one-fiftieth of the thickness of the shell.

OUR BODIES SUSTAIN 30,000 POUNDS OF AIR PRESSURE

Our atmosphere is composed principally of oxygen and nitrogen—gases that we cannot see or smell. Oxygen is a gas that is necessary for life and nitrogen is the gas that dilutes the oxygen. The air also contains water vapor—which gives us dew, fog, rain, sleet, hail and snow—and carbon dioxide—the gas we breathe out and which supplies food for plants.

Although air does not weigh very much the atmosphere exerts a pressure of fifteen pounds upon every square inch of the surface of the earth. This amounts to a pressure of thirty thousand

pounds upon our bodies and they would certainly cave in were it not for the fact that nature has also placed air inside of our bodies so as to balance the pressure from the outside. Climb up to the top of some of our high mountains where the air is thin and your ear drums will soon notify you that the pressure on the outside is not the same as that on the inside of your ears.

Air pressure is indeed a very real thing although we cannot feel it. If all of the air were removed from a building the roof would immediately cave in, because of the air pressure on the outside. Tin cans can be made to collapse by taking the air out of them. In the seventeenth century a remarkable experiment was performed in Germany which showed the enormous force of the pressure of the atmosphere. Two half-spheres about one foot in diameter were placed together and the air was removed from them. These hemispheres stuck together so tightly that they were pulled apart with great difficulty after four teams of horses had been hitched to each.

Of course the human body can become accustomed to different atmospheric pressures. On the highlands of central Asia at an altitude greater than that of our own snow-capped mountains, live millions of people whose bodies have developed through many generations to fit this lessened air pressure.

Our bodies are so constructed that air is absolutely essential to our existence. We could live only a few minutes without it. But our invisible atmosphere is of great advantage to us in many other ways and the earth and the sky would certainly present a very different appearance to us if all of the air should be entirely removed, assuming that we could stay here and observe them.

OUR ATMOSPHERE PROTECTS US IN MANY WAYS

You have all seen photographs of the mountains on the moon and have noticed how black the shadows are. This is due to the fact that the moon has no atmosphere. If the earth should suddenly be robbed of its atmosphere everything would be black dark except in the direct sunlight. If you should step in the shade of a tree or go inside of a building it would be impossible for

you to read this sentence except by the use of artificial light. It is the atmosphere of the earth that makes it possible for us to see terrestrial objects upon which the sun is not shining at that instant.

If the earth had no atmosphere the solar heat which falls upon it during the day would escape into space immediately after sunset and our nights would be bitter cold. Here is another advantage of an atmosphere that we perhaps do not appreciate.

The earth is bombarded by millions of meteors which strike its atmosphere every day. These meteors might cause much inconvenience to us were most of them not completely consumed by the heat which arises from friction in our atmosphere. The people on the moon are not protected in this way by an atmosphere, which probably accounts for the existence of those curious formations known as "lunar craters." Some parts of the moon's surface have the appearance of having been subjected to a bombardment of meteors without the protection of an atmosphere.

Twilight and dawn are due to the presence of an atmosphere around the earth. If we had no atmosphere it would become black dark as soon as the sun dropped below the horizon. You have all noticed the reddish color which the moon takes on when it is totally eclipsed. Here again we appreciate the presence of our atmosphere. Without it the eclipsed moon would be completely dark and invisible.

Without our atmosphere beautiful sunsets would be impossible. When the sun is on the horizon its appearance is affected more by our atmosphere than at any other time because its light must then pass through many more miles of air than when it is on the meridian. Sunlight is composed of rays of light of different colors. At sunset most of these are cut off by the dust particles in our atmosphere and only the red rays from the setting sun are allowed to reach us.

CHAPTER II

The Sun And His Realm

SUN-WORSHIP WAS VERY COMMON AMONG ANCIENT PEOPLES

SUN worship was very common in the early history of all peoples and its influence on the manners and customs of the people may be traced down through the ages. Not only were our ancestors sun-worshippers but many of our own customs are of solar origin. The earliest sun myths have to do with the rising and setting of the sun. The ancient dweller on the seashore believed the setting sun to be devoured by a sea-monster in the evening and disgorged in the morning. The stories of Jonah and the Whale and Little Red Riding Hood are of a type common to all peoples and seem to have had their origin in sun-worship. This is fairly obvious when we consider that version of the latter story which relates how some hunters killed the wolf, ripped him open, and out jumped Little Red Riding Hood, clad in her flaming red coat.

We still have many solar superstitions which are common in certain localities. If the sun shines on a bride she is sure to be happy. If we sleep with our head toward the east we will certainly arise with a headache and if we continue this practice insanity is sure to result. If the sun shines on Candlemas Day (February 2), the wax will prosper; or, as we now have it, if the sun shines on Ground-hog Day (February 2) we will have six more weeks of bad weather. If the sun shines on Easter it will also shine on Whitsunday. We always bury people with their heads toward the west so that when they rise on the last day they can stand upon their feet and face the rising sun.

Who can blame primitive peoples for worshipping the sun? Is it not the dominant member of the solar system, regulating the motions of the planets, and furnishing them light and heat from

an apparently inexhaustible furnace of energy? Is not most of the work of the world today done by energy derived indirectly from the sun? We drive many of our power plants by falling water but there would be no water to fall unless it had first been raised by solar radiation. We use wind pressure for many purposes but there would be no winds if the sun did not heat our atmosphere. The energy locked up in coal, gas and oil came from the sun ages ago.

OUR ANCESTORS WORSHIPPED THE SUN

If we study the history of any ancient race we will find, if we go back far enough, that sun-worship was very common. As far as we can now see sun-worship seems to have originated among the Chaldeans. This type of religion has existed all down through the ages and even in our twentieth century we find traces of it among certain savage races. It was also common among the Persians, Armenians, Syrians and Egyptians. The Israelites found the worship of Baal (the sun) already prevailing in the interior of Palestine (II Kings 17, 16) and Jeremiah tells us that human beings were often sacrificed to the sun.

The Egyptians had several hundred different deities, the principal one being Ra, the sun-god. Pictures of the Egyptian sun-god have been found on many ancient temples and monuments. It is interesting to note that, if we put the definite article before the word "Ra," we get Phrah or Pharaoh, which was their word for king. The Egyptians also worshipped the sun under the name *Osiris*.

The Hindus worshipped *Brahma* (the rising sun). Sun-worship is said to still prevail in Central India where every morning inhabitants face east, stand on one foot, stretch out their hands to the sun, and repeat a prayer to the sun-god which has come down from remote ages. Almost all North American Indians worshipped the sun and sun dances were very common. In the interior of Mexico today the inhabitants throw a kiss at the sun before entering church. The Japanese and Chinese also worshipped the sun. A solar temple is said to have stood in the Mikado's residence.

Why should people not worship the sun if they have not been taught any better? Surely nothing could be more natural. The sun furnishes them light and heat and is responsible, either directly or indirectly, for everything they eat and wear.

The sun was the chief deity of every nation at one time or another and he was also looked upon as the God of Medicine. This is indeed excusable since the sun daily performs millions of miracles on plants, flowers, trees, animal life and human life. Sunshine is the most important thing in the world. The sun-god is still the god of medicine as well as the god of the sun, because sunlight cures rickets and many other human ailments.

APOLLO DAILY DRIVES THE SUN CAR ACROSS THE SKY

The literature of ancient Greece and Rome contains many beautiful myths about the sun-god. He goes by different names in different legends. The Greeks called him Helios, from which is derived our word heliotrope. Sometimes he is Apollo, sometimes Hercules or Perseus, but in every case he is virgin-born, his father being Jupiter, the king of the gods. The Romans worshipped the sun as late as the fifth century, Emperor Constantine being an ardent sun-worshipper before his conversion. The colossal statue at Rhodes is supposed to have been a monument to the sun-god Helios.

Apollo had a beautiful palace in the east where he lived with his favorite attendant, Aurora, the goddess of dawn. According to a classical legend, Aurora with her rose-tipped fingers daily opened wide the pearly gates of dawn and then Apollo drove the sun chariot up into the sky. Higher and higher he would go until noon and then he would descend into the western sky. Finally, after the gates of twilight had closed behind him he would go around by the north so as to be on the job the next morning. Thus primitive peoples saw enacted before their very eyes every day the sublime drama of sun-rise and sun-set. They actually believed that the sun was created for their benefit and that it was driven across the sky by the sun-god Apollo. They didn't worry for a long time about where Apollo went at night, except that he

went around by the north. Finally somebody raised the objection that the sun could not go around by the north since he would then be visible all of the time. The answer came back "he goes around at night, how could you expect to see him?"

We learn from classical mythology that a beautiful young lady by the name of Clytie was desperately in love with the sun-god. Every day as he drove his chariot across the sky she would keep her beautiful face turned in his direction, looking toward the east in the morning and toward the west in the evening. In spite of all her admiration for Apollo she could not win favor in his sight and finally the other gods, feeling sorry for her, turned her into a sun-flower and she still follows with upturned face the shining sun as it goes daily across the sky.

AT DAWN THE SUN FIGHTS FOR ITS LIFE

Apollo, the god of the sun and also the god of medicine, was said to have been the most beautiful and glorious of all the gods. His father was Jupiter and his mother was a beautiful maiden by the name of Latona. Immediately after his birth an immense Python was sent by Jupiter's jealous wife, Juno, to destroy his young son. However, after a terrific struggle Apollo came out victorious. This is just another example of the endless warfare between man and the serpent which can be traced down through history. It is merely symbolic of the daily struggle between light and darkness which occurs every morning at sun-rise, the new-born sun always being the victor.

The sun was also worshipped under the name of Hercules, whose mother was a mortal maiden by the name of Alcmena and whose father was Jupiter, the king of the gods. Two serpents made an unsuccessful attempt to strangle Hercules in his cradle soon after his birth. This again was merely symbolic of the conflict between daylight and darkness. The twelve labors of Hercules, with which all students of classical mythology are familiar, merely refer to the passage of the sun through the twelve signs of the Zodiac during the course of a year. In fact, each of the labors can be identified with one of the twelve signs.

According to an ancient legend Hercules was living peacefully

with his wife and children when Juno drove him mad. He then killed his family. Here again is an allegory. As the sun rises it grows stronger and stronger until its heat finally destroys the fruit of the earth it loves.

In his death Hercules portrays his solar character. He goes out into a western country and puts on the poisoned coat (clouds) which has been sent to him by his wife. The poison infects his system and he tries to cast it off. He then pulls up trees by the roots, builds an enormous funeral pyre, casts himself upon it and dies enveloped in flames. This is the most famous sunset scene ever presented. It is a word picture which is more vivid than any artist could paint. Jupiter then snatches him up into the sky and gives to him in marriage Hebe, the goddess of youth. This is symbolic of the re-birth of the sun at the end of the year.

THE SON OF APOLLO DROVE THE SUN CAR TOO CLOSE TO THE EARTH

One day Apollo met a beautiful nymph by the name of Daphne and immediately fell in love with her. He tried to speak to her but she became frightened and fled, with Apollo at her heels. After a long flight through the forest Daphne finally reached the edge of a river and called loudly to her father, the river god Peneus, for protection. Just as Apollo rushed up to her, her body was changed into a laurel tree. From that time on the laurel was a sacred tree and the laurel wreath was a favorite form of a prize for victories. The story of Apollo and Daphne is symbolic of the daily pursuit of the morning dew by the rising sun. When the heat from the sun reaches the wet foliage the dew soon evaporates and there is nothing left but the leaves.

Apollo had a young son on the earth by the name of Phaeton, who obtained his father's permission one day to drive the sun chariot across the sky in order to convince his playmates that he actually was the son of Apollo. All went well for a while but soon Phaeton was overcome by the terrific heat and fell asleep. The fiery steeds, realizing that no one was holding the reins, went to and fro at pleasure. While they were passing over

northern Africa they came down too close to the ground and scorched a large part of that country and even changed the color of the inhabitants. These suffering people immediately raised such a cry that Jupiter, the king of the gods, hurled a thunder bolt at Phaeton and he dropped lifeless to the ground.

The story of Phaeton driving the sun car probably arose from references to droughts and hot dry spells as caused by the chariot of Apollo being driven by some one who did not know how to guide the horses. The destruction of Phaeton by a thunder bolt of Jupiter is symbolic of the ending of a drought by a rain preceded by lightning and thunder.

Another sun god was Perseus, whose father was Jupiter, and whose mother was the mortal maiden Danaë. Perseus, like Hercules, had many very difficult labors to perform. To him was assigned the difficult task of killing Medusa, that hideous monster whose mere glance would turn any human being into stone. Perseus was the hero of many a classical legend.

THE PROBLEM OF FINDING THE SUN'S DISTANCE IS A DIFFICULT ONE

From very earliest times man has wondered about his distance from the sun and the planets. The problem of finding our distance from the sun obviously reduces to that of finding a base line with which to compare it. When the surveyor wishes to measure the distance between two inaccessible points he first lays off a base line which he measures very carefully. After measuring certain angles he can then compute with great accuracy the distance between the two points.

The sun is so far from the earth that any base line that we might lay off on the earth's surface would be entirely too short to be of any value in computing its distance. We must, therefore, choose a line which extends from the earth to some other heavenly body. Some of the early Greeks attempted to compute the distance to the sun by making use of the distance between the earth and the moon. Their results were very inaccurate. In fact, they were about twenty times too small.

After Kepler had stated his celebrated laws with reference

to the mean distances of the different planets from the sun it became evident that if our distance from Mars, or from any other planet, could be accurately determined we might then be able to compute our distance from the sun. In other words, the researches of Kepler, supplemented by the work of Newton, gave us a true picture of the solar system without any scale of miles. After the invention of the telescope it was possible to determine the distance to Mars with some accuracy and the astronomers began to get some idea as to our distance from the sun. Of course the results at first were somewhat erroneous but the improvement of our instruments and the discovery of new methods of determining the sun's distance have made it possible for us to compute the solar "yard-stick" with very great accuracy.

What is the distance to the sun? As the earth goes around the sun it does not always remain at the same distance from that heavenly body, so that when we talk about the distance to the sun what we mean is the average distance. This is 93 million miles or, to be more exact, 92,897,000 miles. As you stand in the glare of an August sun you can hardly believe that you are 93 million miles from that celestial furnace. However, I assure you that this is a fact.

THE SUN'S DISTANCE HAS BEEN COMPUTED IN MANY WAYS

There are three entirely independent methods for computing our distance from the sun, which may be classified as geometrical, gravitational, and physical. All three methods have been used successfully by many people and they all give the same results.

All geometrical methods depend upon the exact measurement of a base line and the computation of the sun's distance in this way is very similar to the problems solved daily by the surveyor. We can compute our distance from the sun if we can measure the distance from the earth to any planet in miles. During the nineteenth century very accurate computations of the sun's distance were made by measuring our distance from Mars and from some of the planetoids.

At very rare intervals we are allowed to witness a pair of transits of Venus across the face of the sun. If we observe one

of these transits from two stations on the earth differing widely in latitude the planet will be projected onto different parts of the sun's disk. Thus one observer may see Venus pass directly across the center of the sun while the other sees the planet cross the sun in a line parallel to the path reported by the first observer but at some distance from it. The angular difference between the two apparent paths can be measured and the distance from the sun to Venus may then be computed. A slight variation of this method has been used very successfully. Two observers on opposite sides of the earth will see Venus start across the face of the sun at different times. By making use of the difference in time the distance to Venus may be computed.

Two gravitational methods have been used very successfully. One method depends upon the fact that the sun's gravitational effect upon the moon is greater between last quarter and first quarter, when the moon is closer to the sun, than during the other half of the month. Another method makes use of the gravitative disturbances in the orbits of Venus and Mars which are produced by the earth's attraction.

The physical methods are based upon the known velocity of light. Very accurate computations of the sun's distance have been obtained by studying the eclipses of the satellites of Jupiter, by measuring with a spectroscope the speed of the earth around the sun and also by making use of the so-called constant of aberration.

OUR MEASUREMENT OF THE SUN'S DISTANCE HAS BEEN PROVED ACCURATE

The geometrical methods for determining the sun's distance give results by direct measurements. All gravitational methods assume the truth of the law of gravitation. The physical methods assume that light is moving with certain definite velocity. Since all of these methods give the same result these assumptions must be approximately correct.

Every time the astronomer predicts an eclipse of the sun, or of the moon, he makes use of our distance from the sun. When these eclipses occur "on time," as they always do, we realize that not only are the dimensions of the solar system known with very

great accuracy, but also that Newton's Law of Gravitation must be approximately correct and that Michelson and others have measured very accurately the velocity of light.

The enormous distance from the earth to the sun may be illustrated by a problem from geometry. We have learned that the earth is moving around the sun in a closed curve, which is approximately a circle, at the tremendous speed of $18\frac{1}{2}$ miles per second. But the scientists tell us that in one second it falls out of a straight line only one-ninth of an inch. This means that the circle in which we are traveling is so large that any section of it would appear to be a straight line. In fact, the earth will travel two thousand miles before its orbit curves as much as one foot.

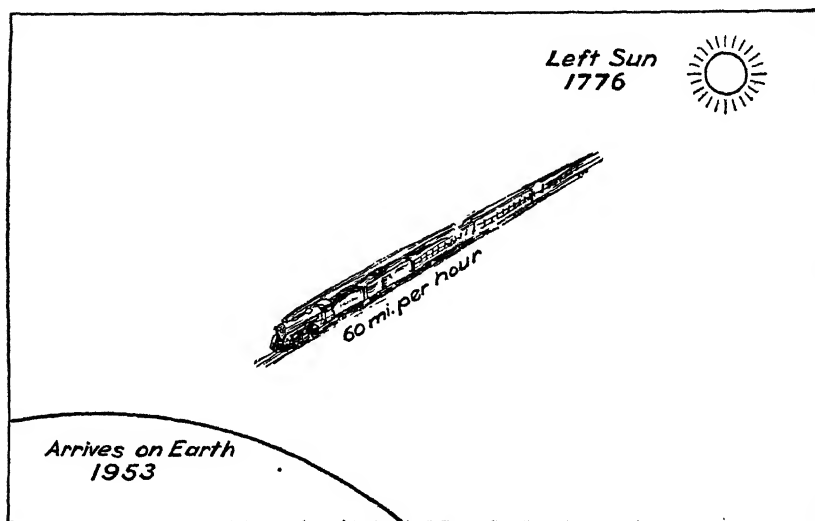
The physiologists tell us that when our fingers touch some hot object a message is sent to the brain and the brain then tells us to move our fingers out of danger. We act immediately, but the fingers are usually burned because a certain amount of time is required for the message to go up the arm. This rate of nerve transmission has been determined by our scientists. Let us now assume that a man on the earth could reach out and touch the sun. How long would it be before he realized that his fingers were burned? If we assume that the message would travel along an arm 93 million miles long at the rate it travels up your arm or my arm that man would have his hand on the sun more than one hundred years before he found out that his fingers were burned. This is a startling statement because we are not accustomed to thinking in terms of millions of miles.

THE SUN'S DISTANCE IS BEYOND HUMAN COMPREHENSION

The problem of finding the sun's distance is one of the most important and most difficult problems of astronomy. As long as this distance is unknown we cannot form any idea of the real dimensions of the solar system or the masses of the different planets. The astronomers tell us that this distance is 93 million miles but this means nothing to the average person. It is easy enough to write the number 93 million. All that is necessary is to write the figures 9 and 3 and then put six naughts after

them. However, there is not a human being on the face of the earth who can comprehend this number. It is simply too great for the human mind. You will be convinced of the truth of this statement by solving a simple problem in arithmetic.

Suppose an express train should make a trip down a straight track from the sun to the earth without a stop, at the rate of sixty miles per hour, how long would it take this train to make



If an express train left the sun on the Fourth of July 1776 it would not be here yet.

one trip? Those of you who are good in mathematics will answer immediately that the trip will require 93 million minutes because the train is running at the rate of a mile a minute and it has 93 million miles to go. This is good arithmetic, but how long is that?

Do you have any idea whether this period of time which you have called 93 million minutes would be as long as a week, or perhaps ten days or two weeks? Do you think that perhaps the train might be on the road as long as a month? You do not have any idea, do you? Of course not, because the number 93 million is entirely too big for the human brain. You may be surprised to learn that if the express train left the sun on the Fourth of July, 1776, the day we signed that immortal document which we call the Declaration of Independence, and had been running down a straight track day and night ever since and had never stopped, it would not be here yet. In fact, although America has gone for-

ward very rapidly in every line of progress since asserting her independence in 1776 until she has reached her present position among the world powers, she has had less than 93 million minutes in which to take her place among the nations.

LIGHT REQUIRES EIGHT MINUTES TO COME FROM THE SUN TO THE EARTH

Astronomers tell us that the sun is 93 million miles away but how many of us actually realize what a great distance this number represents? Let us illustrate with an example which, although leading to a rather startling result, will convince the average person that he is here dealing with a number that means very little to the human mind. Several years ago the discovery was made that light does not move instantaneously, but that it requires time to travel. This is also true of electricity and radio. If you should start a radio message toward the sun it would move at the almost inconceivable speed of 186,000 miles per second, a speed that would take it seven times around the earth in one second. Light moves from one part of space to another at this same rate.

Let us now propose this problem—how long do you suppose it would take a ray of light moving at this tremendous speed of 186,000 miles per second to make one trip from the sun to the earth? Those of you who have studied mathematics will agree that this is a very simple problem. Light is traveling at the rate of 186,000 miles per second and it has a distance of 93 million miles to go. If you divide the second number by the first the result will be 499 seconds, which is a little more than eight minutes. In other words, when you look at the sun in the morning and say, "Good morning, merry sunshine, what makes you wake so soon?" you are not looking at the sun at all; you are looking at the place where the sun *was* eight minutes ago.

The light which strikes your eye now left the sun eight minutes ago and the sun has been climbing up in the sky ever since. In fact, you never see the sun where it *is*, you always see it where it *was* eight minutes ago. I shall never forget how I felt when I first learned this fact. I was a grown man at that time and I looked back at my boyhood days spent on a farm where we

worked from sun up to sun down day after day, and all at once the idea dawned on me that every night of my life I had worked eight minutes over time and didn't know it.

THE SUN'S DISTANCE IS THE "YARD-STICK" OF THE SOLAR SYSTEM

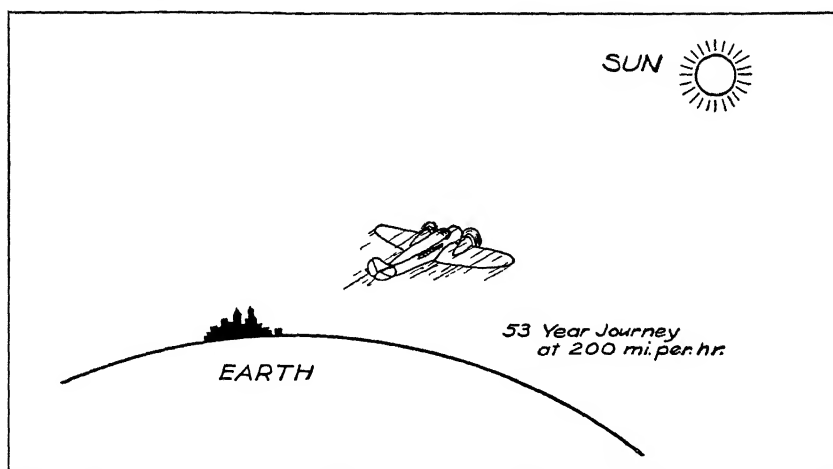
After many years of careful observation and diligent mathematical research the distance from the earth to the sun has been determined and man now has a yard-stick for measuring the dimensions of the solar system. Of course the relative distances of the planets from the sun have been known for many years. That is, we have been using a map without any scale of miles. We have known that Saturn was about ten times as far from the sun as we are, but neither distance was known in miles.

Although the sun's distance has been determined with great accuracy it is so great that it means nothing to the average person. As man becomes more accustomed to the use of the airplane he may wonder whether it will ever be possible for him to make a trip to the sun. If he should start on this trip he would soon learn what a great distance is represented by 93 million miles for, should he travel at the rate of 200 miles per hour and never stop, it would require fifty-three years to make the trip and his friends would probably not recognize him when he got back after having spent 106 years on one trip. In fact, an airplane would have to fly 3730 times around the earth at the equator before it would have flown as far as from the earth to the sun.

Suppose some gigantic explosion should occur on the sun, how long do you suppose it would be before we would hear it? Assuming that sound can travel from the sun to the earth at the rate it travels in our atmosphere we would hear the explosion more than fifteen years after it occurred. Again let us assume that the most powerful piece of artillery that has yet been invented be fired at the sun, and that the ball continues to move all the way from the earth to the sun at the same rate at which it leaves the cannon, this projectile would not strike the sun for six years.

We can truthfully say that the sun is, at least, not in the immediate vicinity of the earth. However, the distance between

the earth and the sun, great as it may appear from our point of view, is very short in comparison with the distances which separate other parts of our universe.



An airplane would require fifty-three years to fly to the sun at 200 miles an hour, but who wants to spend 106 years on just one trip?

ALL WORLDS IN SOLAR SYSTEM BORROW LIGHT FROM THE SUN

The earth is only one of a large number of bodies which are moving around the sun and which form what we call the Solar System. Nine of these bodies, including the earth, are called planets, a word which means a "wanderer." They got this name from the fact that, as seen from the earth, they move about from one part of the sky to another in the course of time while the stars remain fixed.

It is very easy to distinguish a planet from a star. Stars always twinkle but planets never do. Thus the author of the jingle, "Twinkle, twinkle, little star," knew what he was talking about. As we study the nine planets which belong to the sun we should remember that they are not stars and that they do not even look like stars. After a little practice you should be able to pick them out easily whenever they are visible in the sky.

The nine planets shine only by reflected light. If some one should throw a blanket over the sun tonight while several of the

planets are shining in the sky they would disappear immediately but the stars would still shine as brightly as ever. When an astronomer sees a bright planet shining in the evening sky it tells him that "Old Sol" is still on the job although he cannot see the sun at that time.

MERCURY

JUPITER

VENUS

SATURN

EARTH

URANUS

MARS

NEPTUNE

PLUTO

THE NINE PLANETS

The fact that all of the light that is used by the inhabitants of these nine worlds is borrowed from the sun need not be of much concern to us. It is true that we will never be able to repay this loan but the sun contains more than 700 times as much material as all of the nine worlds combined and what little energy we take away from that celestial body will not be missed. The sun is radiating light in all directions and very little of it actually strikes the nine worlds which belong to his domain.

The names of the planets, beginning with the one closest to the sun, are: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. Of course the earth is the most important world as far as we are concerned but the scientists tell us that there are several others which must be much more important members of the Solar System than the little ball upon which we happen to live.

THE WORLDS WERE NAMED AFTER GODS AND GODDESSES

The names of the eight worlds which, together with the earth, revolve rapidly around the sun are well known, yet very few

people know where these planets got their names. You will recall that the ancient Greeks and Romans did not have one God as we have but their religion included a long list of gods and goddesses. They had one god who ruled over the ocean, another god who ruled over the land, a god of war, a goddess of beauty, in fact they even had minor gods and goddesses ruling over lakes, rivers, and trees. If you are familiar with the mythology of these peoples you will recognize the names of all the planets.

The little planet that is closest to the sun is the swiftest moving world in the solar system and was naturally named after Mercury, the messenger of the gods. It was Mercury who had wings on his heels and delivered the messages of the gods with lightning-like speed. The next planet after Mercury is the most beautiful world in the entire sky and was named after Venus, who was the goddess of beauty and also the goddess of love.

The next world beyond the earth has a ruddy color so the ancients named it after Mars, the god of war. Beyond Mars lies the largest world in the entire sky. In fact it is larger than all of the other planets put together. When the ancients discovered this fact they very naturally named the largest planet in the sky after Jupiter, who was the king of the gods. You will recall that Jupiter with his wife Juno lived on Mt. Olympus and ruled over the destinies of gods and men. The world beyond Jupiter was the last one known to the ancients. This world was moving very, very slowly at what they considered the outskirts of the solar system. They, therefore, named it after Saturn, who was the god of time.

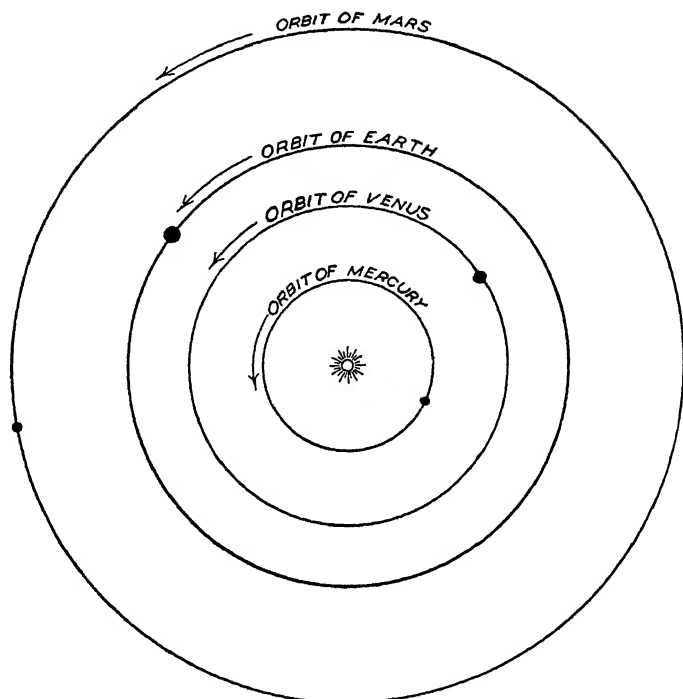
When Sir William Herschel discovered a world beyond Saturn in 1781 he named it Uranus after the god of the sky, and when another world was discovered beyond Uranus in 1846 this planet was called Neptune after the god of the sea. Soon after the new planet was discovered in 1930 it was named Pluto after the third son of Saturn, the other two—Jupiter and Neptune—having already been assigned places in the sky.

THE SOLAR SYSTEM IS A GIGANTIC MACHINE

As we watch the other worlds moving about among the stars we naturally wonder about that gigantic machine which scientists

call the Solar System. How large is it? How long will it run? What is the shape of it?

Let us imagine something flat like a victrola record or silver dollar with a little ball at the center to represent the sun—the motor that makes the machine run. Let us then imagine nine smaller balls placed on the victrola record, all of them in con-



The first four orbits in the solar system drawn to scale.

tinuous motion, rolling on the record round and round the sun. This will give us an idea as to the shape of the solar system. It is flat like a piece of paper or a silver dollar, each planet being compelled by the force of gravitation to move around the sun in a flat plane like the brim of a straw hat.

In order that we may be mathematically exact we should say that the solar system is not quite flat but that it is almost so. The planet Mercury gets farther out of the plane than any of the others (except the newly-found Pluto) but it never gets more than seven degrees out of line. When we recall that the angle between any two minute spaces on the face of a watch is six degrees we realize that this deviation of Mercury is very slight.

For practical purposes we may assume that all of the planets are revolving around the sun in the same plane. Although they are not moving exactly in circles their orbits are so nearly circular that we need not emphasize that point here.

As we look at the machines in some of our factories we sometimes wonder at what the mind of man has created, overlooking the fact that we are living on a little world that is a part of a gigantic machine which is operating silently and everlastingly in the sky. Here is a machine whose dimensions are beyond human comprehension, the diameter being more than 7 billion miles—a distance so great that light, which travels fast enough to go seven times around the earth in one second, requires almost eleven hours to go from one end to the other. Surely here is a gigantic machine which makes us stand in awe and wonder at the power of the creator who could design such a machine and put it into operation.

DIFFERENT WORLDS MOVE WITH DIFFERENT SPEEDS

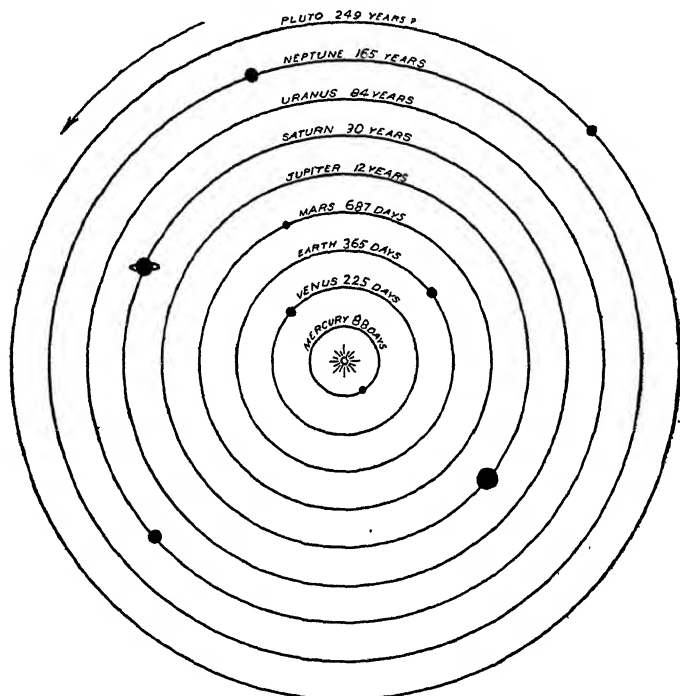
The scientists tell us that there are nine worlds revolving around the sun and that they are all going in the same direction. However, they are not all moving with the same speed. The little planet, Mercury, which is nearest the sun, is the swiftest moving planet we have. Since this planet does not have very far to go it does not take it very long to make one complete trip around the sun. In fact this trip requires only eighty-eight days.

The next planet, Venus, is farther from the sun and moves more slowly than Mercury. Consequently Venus requires a little longer to make its circuit around the sun, making one complete trip every 225 days. The earth comes next and carries us around the sun in 365 days. That period of time seems familiar, doesn't it?

You have perhaps by this time discovered one of the laws which nature has laid down to govern the behavior of the different worlds. The closer a world is to the sun the faster it moves. This is what keeps it from falling into the sun. Both of the worlds between the earth and the sun complete their circuits in

less than one year while those far beyond the earth require many years to make a single trip around the sun.

Just beyond the earth the red planet Mars makes one complete trip around the sun every 687 days. Beyond Mars lies the giant planet Jupiter which swings majestically around the sun every twelve years. Beyond the orbit of Jupiter the planet Saturn, the farthest world known to the ancients, slowly and silently revolves



The farther a planet is from the sun the longer is its period of revolution.

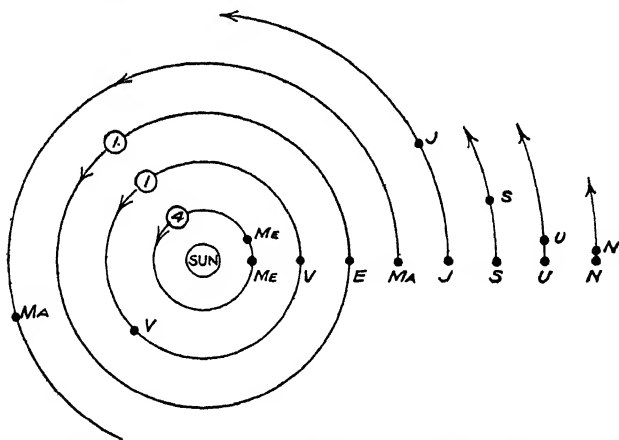
about the sun with a velocity that brings it back to the starting point after thirty years.

Uranus moves even more slowly than Saturn and requires eighty-four years to make one complete trip around the sun. Neptune, the most remote planet known until 1930, moves so very slowly and has so very far to go that while it is making one complete circuit the little planet on which we live goes around 165 times. This planet was not discovered until 1846 so that it has not yet had time to make one complete trip around the sun. The newly discovered Pluto lies beyond Neptune and will prob-

ably require about 250 years to go around the sun and get back to the position among the stars which it now occupies.

EVERY WORLD HAS A DIFFERENT YEAR

What do you mean by a year? You may answer that a year is 365 days. That is true, but suppose you happen to be living on another planet? You say you are thirty years old, but what do you mean? That you have celebrated the Fourth of July thirty times, or that you have hung up your Christmas stocking thirty times? Not at all. You simply mean that you have been living on the earth long enough to make thirty trips around the sun. We must remember that a year is merely a trip around the sun and the length of a year depends upon the planet upon which we happen to be living.



Suppose The Planets Were On Line, Then After One Of Our Years They Will Be In The Positions Indicated

Suppose you are thirty years old, then you have been around the sun thirty times. I, too, am thirty years of age but I live on the planet Venus. Are we the same age? By no means, because while you make two trips around the sun I go around almost three times. The years are different on different planets and each planet makes its own year by its revolution around the sun. What do you suppose the inhabitants of Mars would care about how long it takes the earth to go around the sun? Their

seasons and everything else upon that planet would depend upon the motion of Mars (not the earth) around the sun. They would use a year whose length would be the same as 687 of our days and not 365.

A year is a natural period of time fixed by the planet itself and these periods vary from eighty-eight of our days in the case of Mercury, to 165 of our years in the case of Neptune, or 250 of our years if Pluto turns out to be a real planet. The children who were born on the planet Neptune during the year it was discovered (1846) are not one year old yet.

At some time in the future each and every one of us will have lived his allotted time on this earth and will go out into the great beyond somewhere, we know not just where. After we get out there we may become acquainted with people who formerly lived on these other worlds which are revolving around the sun and we may want to tell them how old we were when we passed away. Let us not forget to tell them which one of these worlds we came off of, otherwise our statement will have no meaning.

EVERY WORLD HAS TWO DIFFERENT KINDS OF YEARS

When we say that every world in the solar system has a different year and that these years vary from eighty-eight of our days to about 250 of our years, we are using the word "year" with reference to the stars. This is the sidereal year, which is the length of time required for a complete trip around the sun. Since we are watching this motion from a position on a world that is flying through space, our observations are entirely different from what they would be if the earth were not moving.

Suppose Venus is exactly between the earth and the sun today. At the end of 225 days Venus will have made a complete trip around the sun but will not then be in line with the earth, because during this time we will have moved about 225 degrees in this same direction. In fact Venus will not overtake the earth until 359 more days have passed. In other words, Venus passes between the earth and the sun every 584 days, so that if Venus is Evening Star tonight it will not be in this same position with

reference to the sun for 584 days. This period is known as the synodic year of the planet.

Each planet has a synodic year that is different from its sidereal year. Let us suppose that Mars is on the meridian at eight o'clock tonight and that it is New Year's Day on Mars. Then after the expiration of 687 of our days Mars will have gone completely around the sun and it will be New Year's Day on that planet again. However, because of our motion Mars will then appear in a different part of our sky at eight o'clock in the evening and its synodic year has not yet ended. At the end of 780 days (93 days after the Martians announce the return of New Year's Day) we find this world back on our meridian at eight o'clock in the evening and its synodic period has been completed.

The astronomers on the other worlds will all agree on the length of the sidereal years of the different planets but they would not agree on the synodic periods. The Martian astronomers are not moving around the sun as rapidly as we are so that they would obtain values for the synodic periods of the different worlds which would not at all agree with ours.

GRAVITATION FURNISHES THE MOTIVE POWER IN THE SOLAR SYSTEM

As we contemplate the gigantic machine—the solar system—which has been operating for millions of years and which appears to be good for many million more, we wonder what keeps this motor in operation and makes it run so smoothly. What is the source from which it secures its apparently inexhaustible supply of gasoline, or whatever is furnishing the motive power? The nine planets are held in their positions and are made to revolve around the sun by that invisible unknown force which we call gravitation.

It has been shown that these invisible chains which are holding the planets to the sun are operating throughout the length and breadth of the universe. In other words, the force which holds the earth in its orbit is just the same as that which holds the moon in its position around the earth, and which causes a stone to fall to the ground when we turn it loose.

The force of gravitation is acting between every two bodies in the universe no matter how large or how small. We do not know what this force is but we do know how it operates. It would be just as hard to give a definition of gravitation as to define electricity. One of the best definitions I ever heard was given by a high school student who said, "Gravitation is that thing which, if we did not have, we would all fly away."

We owe the mathematical statement of the law of gravitation to the great English mathematician, Sir Isaac Newton. We should like to emphasize the fact, however, that Newton did not discover gravitation. People have been familiar with gravitation just as long as there have been any people on the earth. Newton merely discovered the law under which gravitation operates and stated it in mathematical terms.

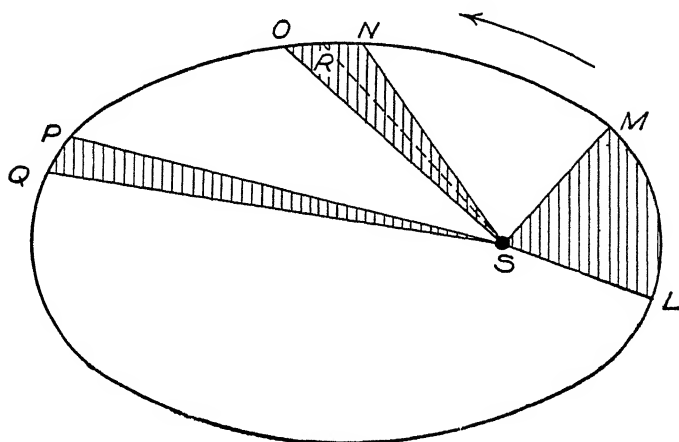
Some people would have us believe that Newton happened to see an apple fall from a tree and that this put him to thinking about gravitation. There is probably about as much truth in this statement as there is in the story about George Washington and the cherry tree, that is, none at all. The law of gravitation as stated by Newton is that "every particle of matter in the universe attracts every other particle with a force that is directly proportional to its mass and inversely proportional to the square of the distance between them."

THE PLANETS MOVE WITH CONSTANT AREAL VELOCITIES

The earth and the other planets move around the sun subject to the Law of Gravitation, but they do not move with a uniform speed. For example, the speed of Mercury varies from twenty-four miles a second in one part of its orbit to thirty-six miles a second in another part. Does it not seem rather strange that nature would build a solar system out of planets that are moving in this irregular fashion? Would it not have been much better to have the speed of each planet remain constant as it goes around the sun?

If we look into this question a little further we will discover

that each planet is moving with a uniform speed, but it is not the kind of speed we are accustomed to thinking of. The earth is not moving around the sun in a circle but in an ellipse with the sun a short distance out of the center so that we are closer to the sun at some times than at other times. Let us now assume that the earth and the sun are connected by a straight line. As the earth moves this imaginary line turns like the spoke of a wheel. Now the secret of the motion of the earth around the sun is that this imaginary line sweeps over equal areas in equal times. In



The nearer a world gets to the sun the faster it moves. If the shaded areas are equal then the earth moves from L to M, N to O, and P to Q in equal time intervals.

other words, this line will sweep over an area during any week in January that is equal to the area swept over during any week in July or at any other time of the year. This means that when the earth is closest to the sun it must move fastest in order to preserve this equality of areas.

This law, which states that the line joining the sun and the earth sweeps over equal areas in equal times is known as the "Law of Areas" and was discovered by the German astronomer, Kepler, who is known as the Father of Mathematical Astronomy. Kepler made a brilliant "guess" that all the planets were moving around the sun subject to this law, but Newton proved mathematically that this law must hold for every heavenly body that is moving around some other body subject to a central force—in this case, gravitation. Thus nature has arranged things in

an orderly fashion so that the areal velocity of every planet is constant but not the linear velocity.

THE MILE IS NOT A CONVENIENT UNIT IN SOLAR SYSTEM

Man constantly finds it necessary to measure the different objects with which he comes in contact and to compare their lengths, areas, volumes, weights, temperatures, etc. In order that his results may be accurate he has agreed upon certain units of measure and he usually makes use of the unit which happens to be the most convenient.

If you were asked to determine the width of a certain table you would probably give the result in inches, but if you should desire to measure the length of a building you would probably use a tape line and express the result in feet. This unit, however, is not convenient for measuring distances between two points on the earth. Suppose the speedometers on our cars were so made as to register in feet. Would we not be surprised after driving from New York to Chicago to learn that the distance was 2,772,000 feet? This may be accurate, but it is not convenient because we do not like to deal with such large numbers. We prefer to choose a unit that is equal to 5,280 feet and express the distance in miles. It is convenient to use the mile as a unit for measuring distances on the surface of the earth for if we measure completely around the equator we would find only about 24,000 of these units.

Since the distance from the earth to the sun is 93 million miles it would obviously be very inconvenient to express the distances in the solar system in terms of miles. It is better to use a much longer unit and the one that has been chosen is the distance from the earth to the sun. This distance is called the "astronomical unit" and, when expressed in miles, is represented by the number 93 million.

Thus we say that the distance from the sun to Saturn is ten, which merely means that Saturn is ten times as far from the sun as the earth is. By making use of this new unit of measure it is possible to express the distances of the planets from the sun

by numbers less than one hundred, whereas if these distances were expressed in miles most of the numbers would be greater than one hundred million. If the distance in miles from the sun to any planet is desired it is only necessary to multiply the number representing this distance by 93,000,000.

THE PLANETS ARE SPACED ACCORDING TO A CURIOUS LAW

There is a very interesting law, discovered by the astronomer Bode in 1772, which may be used to compute the average distance from the sun to the different planets. We say "average" distance because, as we have already learned, the sun is not at the

<i>BODE'S LAW</i>				
<i>Mercury</i>	<i>Venus</i>	<i>Earth</i>	<i>Mars</i>	
4	4	4	4	4
<u>4</u>	<u>3</u>	<u>6</u>	<u>12</u>	<u>24</u>
.4	.7	1.0	1.6	(2.8)
<i>Jupiter</i>	<i>Saturn</i>	<i>Uranus</i>	<i>Neptune</i>	<i>Pluto</i>
4	4	4	4	4
<u>48</u>	<u>96</u>	<u>192</u>	<u>384</u>	<u>768</u>
5.2	10.0	19.6	38.8	77.2

exact center of the orbit of any planet. This law does not seem to rest upon any mathematical basis but it gets the results just the same, except in the case of Neptune and Pluto.

Let us arrange in a horizontal line a series of 4's as shown above, using ten terms in order to make allowance for the missing planet between Mars and Jupiter. Now put 3 under the second 4, 6 under the third 4, etc., each number in the second line being obtained by doubling the number immediately before it. Add these numbers and divide the sums by 10. The figures in the last line represent the average distances from the sun to the

different planets with the exception of Neptune, whose distance is only about 30, and Pluto, whose distance seems to be about 40. In other words, the average distance from the sun to Mars is 1.6 astronomical units; that is, 1.6 times 93,000,000 miles, or 149,000,000 miles.

When Bode's Law was published Saturn was the last known planet and the law worked beautifully provided a gap be left in the table between Mars and Jupiter. Nine years later Sir William Herschel discovered Uranus in the exact place provided for it by Bode's Law.

You may wonder why this curious law breaks down at Neptune. The greatest wonder is that it holds up so far. Even though Bode's Law is no good beyond Uranus it has certainly served a very useful purpose in the development of our knowledge about the solar system.

OUR LIVES ARE TOO SHORT TO FLY TO OTHER WORLDS

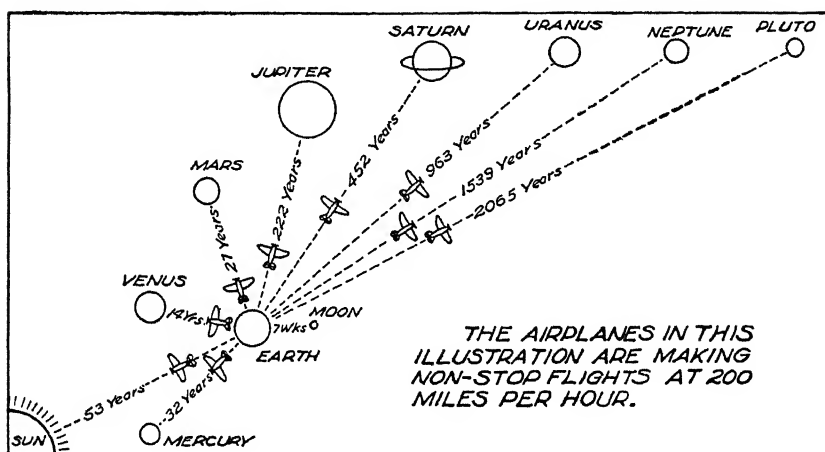
A fairly accurate picture of the orbits of the different planets may be drawn by placing a dot on a piece of paper to represent the sun and then drawing a series of concentric circles around this point with radii proportional to the numbers given by Bode's Law. It will be seen that four of the planets are rather close to the sun and the others are much farther away.

By means of Bode's Law we can compute the distance from the earth to any one of the other worlds but these distances do not mean much when expressed in miles. Perhaps we can best appreciate the dimensions of the solar system by making use of several examples. Suppose we should start on a trip to Venus in an airplane at the rate of 200 miles per hour. Do you realize that we would have to spend 14 years in the air before we reached that planet? Twenty-nine years would be required for a trip to Mars and 222 years for a trip to Jupiter.

We sometimes hear people talk about making trips to the moon and to the different planets in airplanes. Before we start on one of these trips we should remember that there is plenty of air around the earth and there is some air around Mars but

there is no air in between the two planets and we might find ourselves in distress when we got to the place where there was no air for our airplane to ride on.

Even if this difficulty could be eliminated, trips to some of the planets would be impossible at the present time since we would not live long enough to complete the trip. Suppose our airplane could fly at the rate of 1000 miles per hour, it would require 40 years to go to Jupiter and the same length of time to get back and who wants to spend 80 years on one trip?



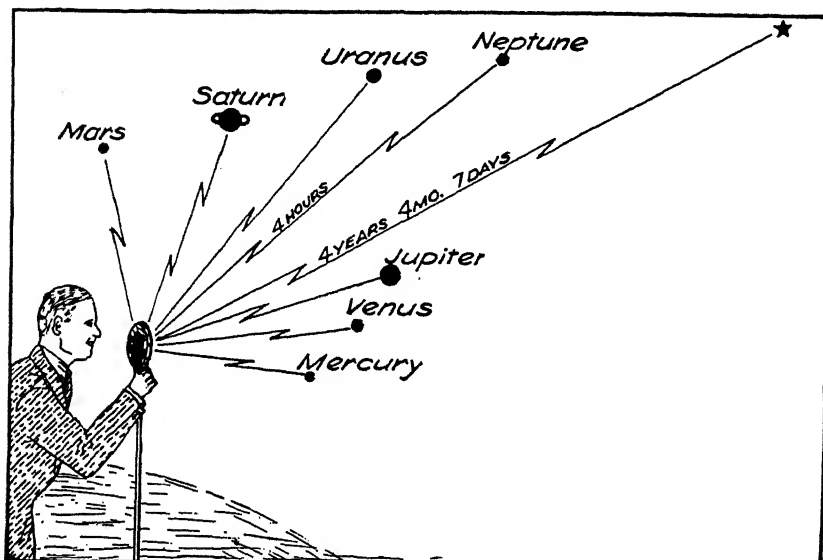
We can now readily understand why these distances mean absolutely nothing to us when measured in the same kind of units which we are accustomed to using on the earth. It means much more if we will just say that the distance to Jupiter is 5.2 units and let it go at that. Of course we understand that this simply means that Jupiter is a little more than five times as far from the sun as the earth is.

A RADIO MESSAGE WOULD REACH THE NEAREST STAR IN FIFTY-TWO MONTHS

All of the worlds, except Mercury, Venus and Mars, are so far from the earth that we can hardly expect to visit them in person. Even if we could fly through space in an airplane at the rate of 200 miles per hour we would die of old age before we

finished our trip. If transportation is too slow, then how about communication? We cannot say when we may be able to establish communication with other worlds but we may mention just one practical difficulty as an illustration of the immense distances which separate the earth from the different planets.

Let us assume that I have a friend who lives on the planet Neptune. In the morning at eight o'clock just as my school day



A radio message would reach Neptune in four hours, but a listener on the nearest star would not hear it for four years, four months and seven days.

begins I step before the microphone and say, "Good morning, Mary, how are you this morning?" I then go about my business of teaching school. This radio message starts out through space at the terrific speed of 186,000 miles per second and in four hours and two minutes Mary hears what I have to say. She replies immediately by radio and that afternoon after four o'clock when my school day is over I hear a voice from my loud-speaker saying, "I am very well, thank you, how are you?" This is the very best we can do on account of the great distance.

Even though much time is required for this conversation I am thankful that my friend lives on a planet, even though it be the farthest planet, rather than on a star. For if she lived on a star, even on the closest star to the earth, it would require 4

years, 4 months, and 7 days for my radio message to reach her and when her answer came back I would be about nine years older and I would probably have forgotten what I was talking about. This illustration will surely convince you that, although distances from one planet to another are almost beyond human comprehension, there are other distances in the universe which are even greater than these.

The astronomical unit—93 million miles—which is so convenient for expressing distances between the members of the solar system is entirely too short to be of any value when measuring the distances to the stars. If the distance to the nearest star be expressed in terms of this unit it will be represented by the number 272,000.

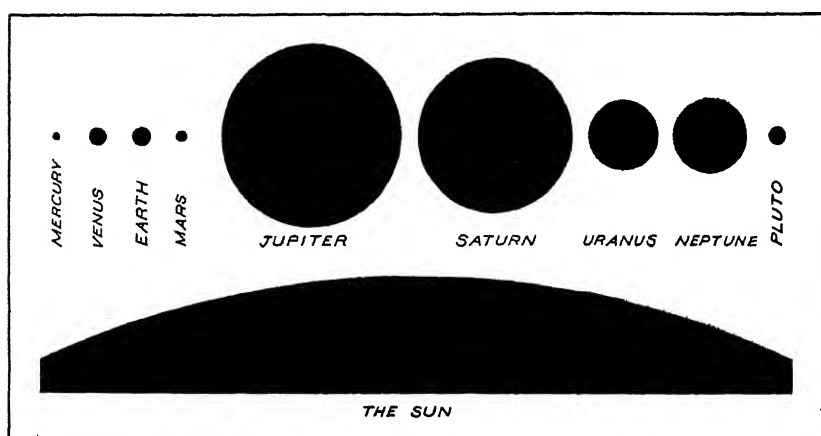
THE EARTH IS ONE OF THE SMALLEST OF THE PLANETS

How large are the nine worlds that compose the sun's family? The diameters of all of these worlds have been measured except that of the newly-discovered Pluto. Since very little is now known about this new planet we will confine our attention to the other eight worlds for the present. We will not mention their diameters in miles at this time but will just say that there are four large worlds and four small worlds and that unfortunately the earth is one of the small ones.

Jupiter is the largest planet of all and is about 1200 times as large as the earth. Mercury is the smallest planet, being only one-eighteenth the size of the earth. The eight planets may be conveniently grouped in pairs. The largest pair is made up of Jupiter and Saturn, Jupiter being somewhat the larger of the two. The next pair is composed of Uranus and Neptune, each of which is about sixty times as large as the earth. The next pair consists of the earth and Venus, which are about the same size. The smallest pair is made up of Mars and Mercury, both of which are much smaller than the earth.

Sir John Herschel has given us the following illustration of the dimensions of the solar machine:—"Choose any well-levelled field. On it place a globe two feet in diameter. This will represent

the sun. Mercury will be represented by a grain of mustard seed on the circumference of a circle 164 feet in diameter for its orbit; Venus, a pea, on a circle of 284 feet in diameter; the Earth, also a pea, on a circle of 430 feet; Mars, a rather large pin's head, on a circle of 654 feet; the planetoids, grains of sand, on orbits having a diameter of 1000 to 1200 feet; Jupiter, a



Most of the worlds are larger than the earth, but all are insignificant in comparison with the sun.

moderate-sized orange, on a circle nearly half a mile across; Saturn, small orange, on a circle of four-fifths of a mile; Uranus, a full-sized cherry or small plum, upon the circumference of a circle more than a mile in diameter; and, finally, Neptune, a good-sized plum, on a circle about two and one-half miles in diameter." On this same scale the nearest star would be represented by a globe about two feet in diameter and 8000 miles away—on the opposite side of the earth.

SATURN IS THE LIGHTEST PLANET

Every patriotic citizen is proud of his state, his nation, and his planet. We can boast of many things for which our world is famous but size is not one of these. If the diameter of the earth be chosen as unity the diameters of the eight planets may be expressed by the following numbers: Mercury, 0.39; Venus,

0.973; Earth, 1.000; Mars, 0.531; Jupiter, 10.95; Saturn, 9.02; Uranus, 4.00; Neptune, 3.92.

We live on a very small planet, and we look with admiration at our big brother world, Jupiter, which is larger than all the other seven worlds combined. That statement sounds strange, doesn't it? But let us see what the figures show. It is a well-known fact that the volumes of spheres vary as the cubes of their diameters. If we cube the numbers listed above we get 0.06, 0.92, 1.00, 0.15, 1313.01, 733.87, 64.00, 60.24, and it is obvious that the number 1313, which corresponds to Jupiter, is larger than all the others combined. Add them up and see.

The four planets closest to the sun are the smallest and they are also the heaviest planets per unit of volume. The four large planets are all outside of the orbit of Mars and none of them are very dense. In fact several of them seem to be still in a semi-gaseous state so that they give a certain amount of light and heat. If we should ask, "Which planet weighs the most per unit of volume?" we should have to reply that of all the planets revolving around the sun the earth is made of the heaviest material. Saturn is the lightest of all.

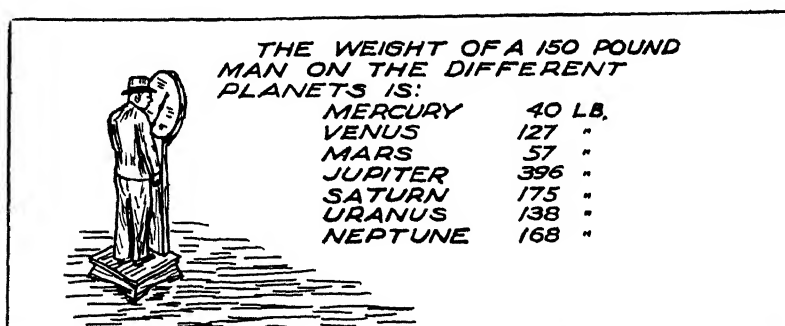
Let us compare the weights of the different planets per unit of volume. What do you suppose would be the weight of a gallon of the average material of which the different planets are made? We have already seen that the earth is the heaviest planet of all. A gallon of the average material of which the earth is made would weigh 55 pounds, a gallon of material from Venus weighs 52 pounds, from Mercury 49 pounds, from Mars 39 pounds, from Jupiter 14 pounds, from Uranus 13 pounds, from Neptune 13 pounds, and from Saturn 6 pounds. A gallon of water weighs about eight and a half pounds, so that a gallon of the average material of which Saturn is made weighs less than a gallon of water. That is, Saturn would float in water.

A MAN WOULD WEIGH ONLY ABOUT SIXTY POUNDS ON MARS

Modern research has revealed the fact that conditions are different on the various planets. The years are of different

lengths, the days are of different lengths, the seasons are much longer on some planets than on others, and planets differ in size, in density, and in many other respects. In fact, if you should move to some other planet you would not even weigh the same that you weigh on the earth.

And that raises another question, "Why do you weigh anything at all?" You weigh 150 pounds not because your name is Jones or Smith or Brown, but because you stay on the surface of the earth. Weight is merely our old friend gravitation. The earth pulls on us with a certain force and we say that we have a certain weight.

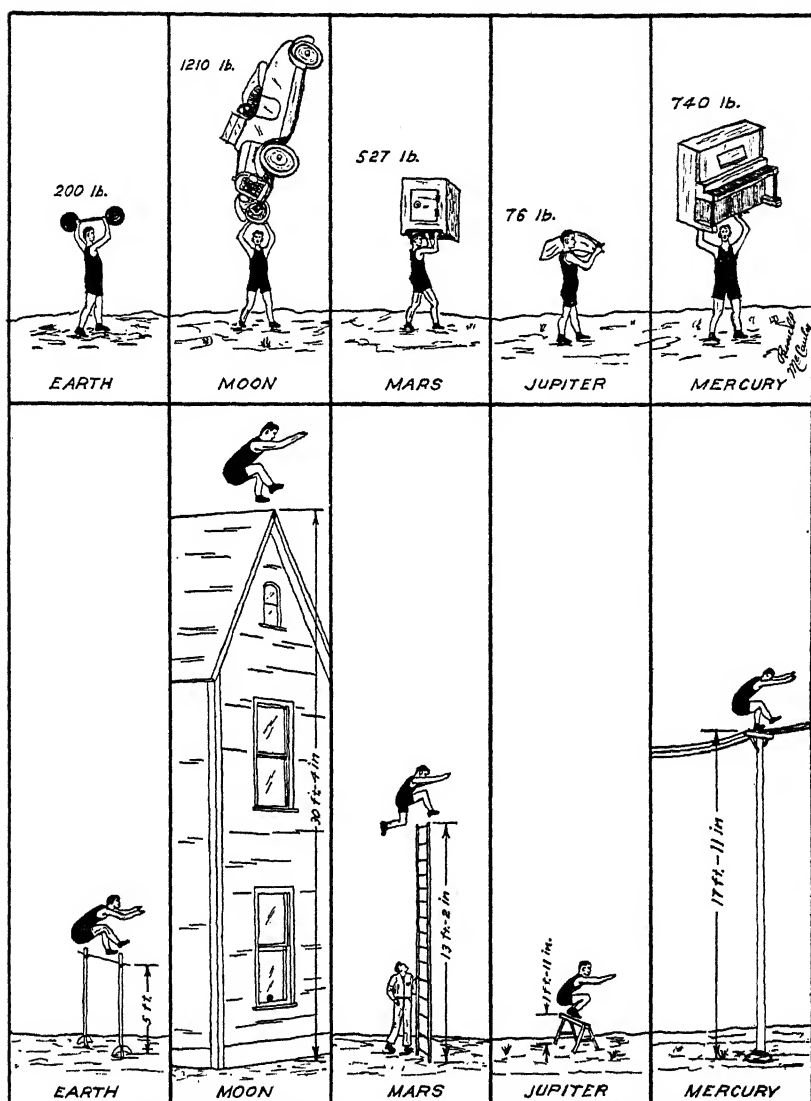


If you should move to Mercury the gravitative attraction between you and the planet would not be very great and you would weigh only 40 pounds. On Venus your weight would be 127 pounds, and if you prefer to live on Mars you would weigh 57 pounds. If you should like to increase your weight you might move to Jupiter where you would weigh 396 pounds. If that is a little too heavy you might prefer to live on Saturn where you would weigh only 175 pounds, or on Neptune where your weight would be 168 pounds, or finally on Uranus where your weight would be 138 pounds. In other words, your weight depends entirely upon where you happen to be.

WE WOULD ALL BE STRONG MEN ON MARS

It is obvious that the number of pounds a man can lift depends upon how strong gravitation happens to be at the place where he is living. If you can lift only 100 pounds on the earth, you might

move to Venus where you could lift 118 pounds or to Mars where, with the same amount of energy, you could lift 263



Our "strength" depends upon where we happen to live.

pounds, or to Mercury where you could lift 370 pounds. If you prefer to lift only small weights with this same amount of energy, you might take your exercise on the planet Jupiter where a weight of 38 pounds is equivalent to 100 pounds on the earth,

or on Saturn or Neptune where you could lift 85 or 89 pounds respectively. If you prefer to live on the planet Uranus you could lift 109 pounds with the same energy that you expend on 100 pounds on the earth.

Let us see what would be the result of taking our daily exercise on some of the other worlds. Suppose we are in the habit of jumping over a hurdle five feet high and we should undertake to jump with this same energy on Mars. Due to the lessened force of gravity we would rise thirteen feet into the air before we started down and, upon striking the ground, we would be surprised that no limbs were broken. If we were on the moon we could jump over a house thirty feet high, but with this same energy we could get only about two inches above the surface of the sun. Thus it may be truly said that the dimensions of the human body are determined by the force of gravity and man is really a creature of his environment.

People sometimes get excited about the rate at which the population of the earth is increasing—30 million a year. They wonder what will happen when the western hemisphere can no longer absorb the excess population of Europe and Asia. By the time this condition becomes acute man will have learned how to go to Mars and Venus. When the human race begins to spread out over the other worlds gravity will cause man to do some curious "stunts," as Mr. H. G. Wells has so cleverly pointed out in "The War of the Worlds." After all of the nine planets have become densely populated we still have at our disposal about 1200 small planets—the planetoids.

TWENTY-SIX MOONS CIRCLE AROUND SIX OF THE WORLDS

We usually think of the Solar System as consisting of nine planets and twelve hundred planetoids revolving about a central sun. Recent researches have shown that meteors and comets also move around the sun and belong to the Solar System. In addition to the planets, planetoids, meteors and comets, there are twenty-six other bodies that belong to the Solar System but do not revolve around the sun. These bodies are moving around the

different planets and are known as satellites, or moon. Four of these satellites have been discovered since 1900 and other faint ones probably await discovery.

Let us see how these moons are distributed among the different planets. Since each moon is controlled by the gravitative attraction of the planet to which it belongs we would naturally expect the largest planets to have the most moons and this is just what we find to be the case. Mercury has no attendant and neither has Venus. The part of the sky near each of these worlds has been carefully studied many times in an effort to discover a small moon but our efforts have so far been in vain. Many photographs have been made and carefully scrutinized without success and we are now convinced that neither of the worlds between us and the sun is attended by a satellite.

The earth has one satellite which has been known ever since man has been on the earth. This satellite is usually called the Moon, in spite of the fact that there are twenty-five other moons in the solar system. Mars has two very small attendants, Deimos and Phobos, which were discovered in 1877. Jupiter has nine moons, four of which—Europa, Ganymede, Io and Callisto—were picked up by Galileo as soon as he invented the telescope in 1610. These satellites compare in size with our moon. The other five are very small and have been discovered since 1892.

Saturn also has nine attendants, one of which is larger than our moon. These satellites were discovered at intervals between 1655 and 1899 and were named Mimas, Enceladus, Tethys, Dione, Rhea, Titan, Hyperion, Iapetus, and Phoebe. Four small moons—Ariel, Umbriel, Titania and Oberon—revolve about

EARTH	<i>The Moon</i>	SATURN	<i>Dione</i>
MARS	<i>Deimos</i>		<i>Rhea</i>
	<i>Phobos</i>		<i>Titan</i>
JUPITER	<i>Europa</i>		<i>Hyperion</i>
	<i>Ganymede</i>		<i>Japetus</i>
	<i>Io</i>		<i>Phoebe</i>
	<i>Callisto</i>	URANUS	<i>Ariel</i>
SATURN	<i>Mimas</i>		<i>Umbriel</i>
	<i>Enceladus</i>		<i>Titania</i>
	<i>Tethys</i>		<i>Oberon</i>
	NEPTUNE	<i>Titon</i>	

All of the twenty six satellites in the solar system have names except five tiny companions of Jupiter.

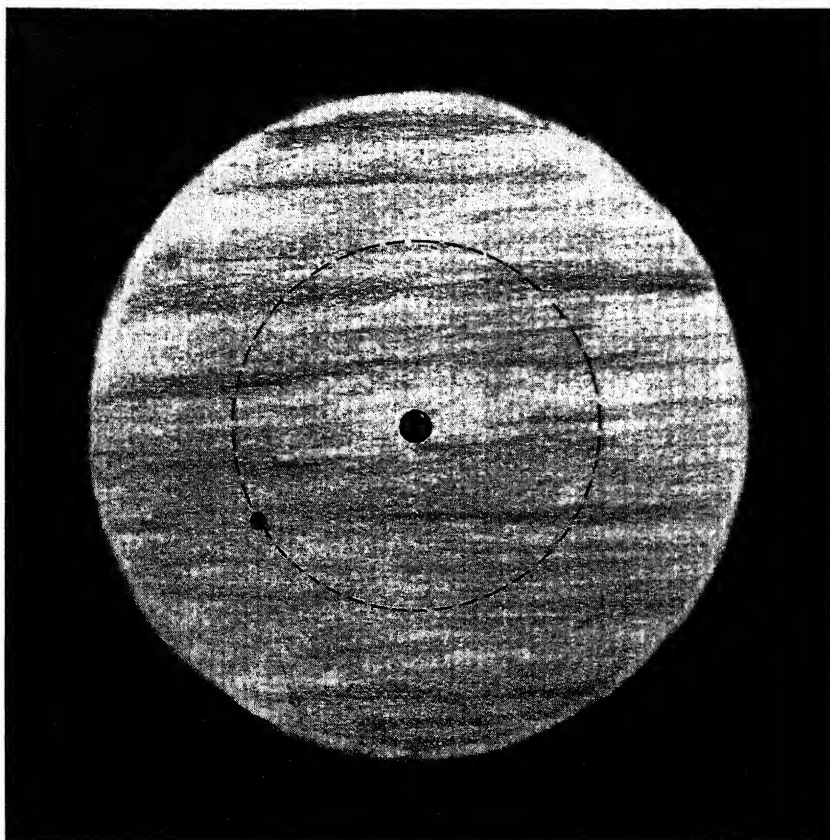
Uranus. The two largest were found in 1787 and the other two in 1851. Neptune seems to have only one attendant—Triton—which was picked up soon after the planet was discovered in 1846.

THE SUN IS ONLY A PRIVATE IN THE HOST OF HEAVEN

It is true that we of the twentieth century now realize that the sun is only a private in the host of heaven—a single star among millions, thousands of which probably exceed him in size and brightness. But he alone among the countless myriads of stars is near enough to affect terrestrial affairs in any sensible degree. Who can watch the mid-summer sun rising in all its splendor and not understand why ancient people worshipped Apollo and the other sun-gods? The sun gives us light, it furnishes us heat, and to him are we indebted for life itself. We could live without the moon, and the stars are not at all necessary for our existence, but the sun we must have or we perish.

The sun is many times larger than any of the planets which go around it. Its diameter is 864,400 miles, or 109.1 times the diameter of the earth, so that the men whom Jules Verne sent around the earth in eighty days would require twenty-four years for a trip around the sun and an express train, running at the rate of a mile a minute, would not complete a circuit around the equator of the sun for five years. The sun has 12,000 times as much surface area as the earth and its volume is 1,300,000 times as great as that of the earth.

Let me give you an illustration of the size of the sun. Suppose the sun were hollowed out into a shell like an egg-shell and the earth were placed at its center, then the moon would have to come inside of the shell too. The distance from the center of the shell to the surface would be about 432,000 miles and, since the moon is only 238,000 miles from the earth, there would be plenty of room inside of the sun for the moon to make its monthly trip around the earth and another moon nearly twice as far away. You can now see the absurdity of the notion that the sun was driven across the sky in a chariot in order to furnish light for



There is plenty of room inside of the sun for the moon to make its monthly trip around the earth.

the inhabitants of the earth. The sun is radiating light and heat in all directions and, if it were created for the sole purpose of warming and lighting the earth, the creator certainly carries on his business in a very wasteful manner.

THE SUN IS 700 TIMES HEAVIER THAN ALL THE PLANETS COMBINED

Not only is the sun larger than the earth but it is much larger and heavier than all of the nine planets combined. In fact, if all of these worlds were thrown into a gigantic furnace and were molded into a single planet it would take 700 of these new

planets to weigh as much as the sun. The sun weighs more than a solid iron ball as large as the orbit of the moon.

That gigantic machine in the sky which is composed of the sun and nine planets is rightfully called the "solar" system, since it is nearly all "sun." As a matter of fact, the sun contains more than 99.8% of the mass of the entire system.

You may perhaps be acquainted with the planetesimal theory of evolution according to which the material of which the planets were made was actually pulled out of the sun. When we appreciate the immensity of the sun compared with the planets we can easily understand how this might be possible since one-seventh of one per cent of the material in the sun would be sufficient to form all of the nine planets.

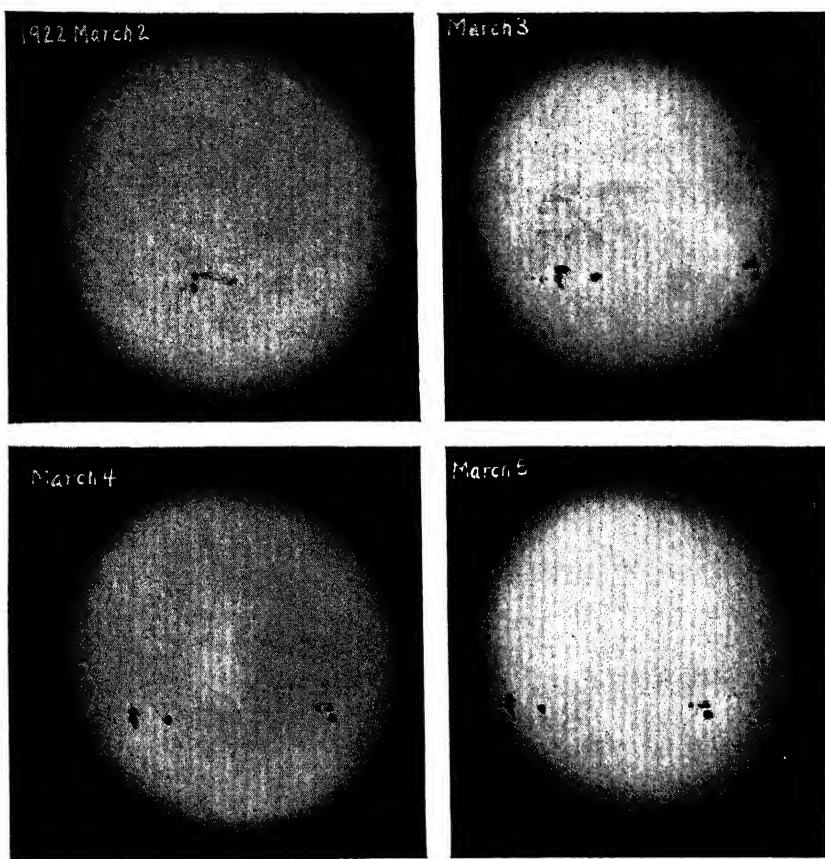
In the sun we live and move and have our being. He is monarch of all he surveys. There is only one law in his realm and that law is gravitation. This law operates throughout space and all parts of the universe are moving promptly and silently in obedience thereto.

Although it does not seem possible for us to give a definition of gravitation, I wonder if we appreciate the fact that we owe our very lives to this invisible force. We go about our daily affairs unmindful of the fact that as we whirl around the gigantic sun at the rate of eighteen and one-half miles per second, the invisible chain of gravitation is holding our little world in its proper position. We feel safe and secure because we know that the sun weighs 332,000 times as much as the earth, so that it will probably hold us fast for some time to come. However, I shudder when I think about what would happen to the inhabitants of the earth if at any instant the chain should be broken and gravitation should cease to operate. Our little world would then fly off at a tangent into space and all life on the earth would come to an end.

THE SUN ROTATES ONCE IN TWENTY-FIVE DAYS

The force of gravity on the surface of the sun is almost twenty-eight times its force on the earth. Consequently the

objects with which we are familiar would be very heavy if transported to the sun. A man who weighs 150 pounds would weigh almost a ton if he should move to the sun, and if he can lift 100 pounds on the earth he would find that, with the same amount of energy, he could lift only three and one-half pounds on the sun.



The changing position of the sun-spots reveals the rotation of the sun.—Yerkes Observatory.

The sun is rotating on its axis with an average period of about twenty-five days. I use the word "average" because different parts of the surface of the sun rotate with different periods, the time of rotation being shorter at the equator than on either side. When we take into consideration the immense size of the sun we are astonished at the rapidity with which a point on its

equator must be moving. The rotation of the sun carries such a point a distance equal to that from San Francisco to New York City in about five minutes, a thing which is accomplished by the rotation of the earth only after several hours.

The visible surface of the sun is called the photosphere, which means the "light sphere." This is the surface from which most of the sun's energy is radiated. Outside the photosphere, and separated from it by a layer of cooler gases—known as the reversing layer—is the scarlet chromosphere, or color sphere, which is largely composed of calcium, hydrogen and helium.

Anyone who will take the trouble to look at the sun through smoked glass will discover that the photosphere is not of a uniform shade but it contains quite a number of dark spots. These sun-spots, which are the most conspicuous and interesting objects upon the surface, are found in two belts, one on each side of the equator and parallel to it. Sun-spots change their appearance very rapidly. They come and go periodically, the maximum number occurring every eleven and one-seventh years. In other words, if this is a year of sun-spot maximum we may be sure that there will be comparatively few spots on the sun five and a half years from now, but that after about five and a half more years the sun will contain approximately as many spots as are to be found on it today.

THE SPOTS ON THE SUN ARE MUCH LARGER THAN THE EARTH

Since the sun was supposed to be absolutely perfect and was looked upon as an object of worship by many people, we can imagine the reception which was given Galileo's announcement in 1612 that the sun had on its surface many dark spots which moved across its face from day to day. The Chinese claim to have records of the observation of these objects long before the time of Galileo. This is not remarkable since large spots are visible to the unaided eye. Although sun-spots appear dark in contrast with the brilliant photosphere which is visible in the background, they are really brighter than a calcium light. The diameters of spots vary from about 500 miles, which is probably

as small a spot as we could see with our present telescopes, up to about 60,000 miles.

The life of an individual spot is very short, many of them lasting only a few hours. Only a very few last through one complete rotation period of the sun, although one spot is said to have remained visible for about eighteen months (1840-41). Sun-spots seem to have a tendency to recur at points on the surface where spots have disappeared before. This suggests that they are probably due to some disturbance below the surface of the photosphere which is invisible through the telescope. Frequently a large spot breaks up into several small ones which fly apart very rapidly.

Many theories have been proposed to account for the existence of sun-spots. It has been suggested that they are due to eruptions on the sun. Not that they are the craters through which the eruptions break, but rather cavities which have resulted in the neighboring surface and in which cooler (and consequently darker) gases have collected. It has also been proposed that the sun-spots are due to meteors striking the sun. This does not explain their peculiar distribution. Sun-spots do not appear on all parts of the sun's surface, but are usually confined to two belts between latitudes 6° and 40° in both the northern and southern hemispheres.

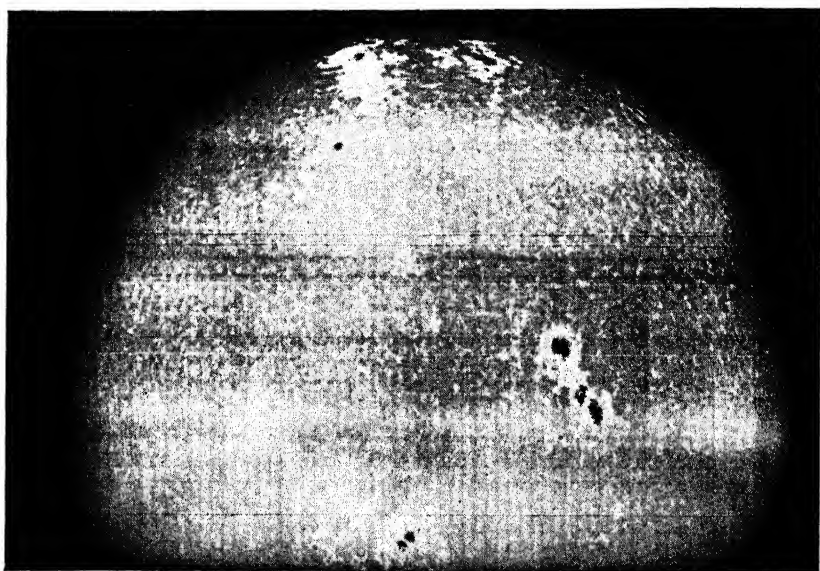
Authorities today are more inclined to believe that sun-spots lie at very different levels and that they are disturbances in the solar atmosphere corresponding perhaps to cyclones on the surface of the earth. Although much attention has been devoted to sun-spots during recent years the question as to their nature and origin has not yet been definitely answered.

SUN-SPOT CYCLES

For some time we have known that outbreaks on the sun's surface—sun-spots—occur at regular intervals of about eleven and one-seventh years, but so far man has failed to discover the cause of this regular beating of the pulse of nature. A record of sun-spots during the past forty years exhibits very clearly four of these gigantic "heart-beats."

The years 1891 and 1892 were noted for intense solar activi-

ties and in February 1892 a spot more than 100,000 miles in length and having a surface area of more than two billion square miles appeared. Early in the autumn of 1893 a maximum occurred with the sun-spot zones dotted with spots, and in 1894 many large and very interesting groups of spots appeared. During that year a remarkable eruptive prominence which extended more than 70,000 miles above the solar surface and disappeared in about ten minutes was observed. A few large spots were seen



Violent eruption of July 17, 1928, projected against the sun's disk.
—Yerkes Observatory.

as late as 1896, one of which had an area of nearly 400 million square miles and passed entirely across the face of the sun.

The next maximum period was near the end of 1905, but in 1903 a gigantic group of spots more than 135,000 miles long and 39,000 miles wide went across the solar disk and in January 1905 appeared what was probably the largest single sun-spot for many years. During the two years immediately preceding the next maximum period in 1917 the sun's surface was especially active and several giant groups of spots appeared.

The next maximum period was unique in several ways. Not only was the period of time unusually long but there were two peaks of greater activity separated by a period of about two

years. The first occurred about the middle of April, 1926, and the second in July 1928. On July 17, 1928, two very interesting eruptions were photographed. Both of these disturbances were very brilliant and broke out in the vicinity of a group of small spots near the center of the solar disk. The first eruption was in the shape of a spiral about 25,000 miles in diameter and lasted only a few minutes, although its scattered remnants were visible for an hour. Before the fragments of the first eruption had faded completely out a second one about 16,000 miles long broke out nearby and obtained its greatest brilliancy within three minutes, its total life being only about ten minutes.

SUN-SPOTS CAUSE ELECTRICAL DISPLAYS

Do sun-spots have any influence on the earth? Well informed people know that the moon is a small, dead world which has no effect on the earth except to cause the tides, but with the sun it is a different story. Since the human race—and probably the earth itself—owes its existence to the sun, it would indeed be remarkable if a gigantic disturbance could occur on the surface of the sun without having some effect at least on the atmosphere of the earth. It must be remembered that many of the spots that result from solar activity are so large that our little world would be swallowed up if thrown into them, and that when they appear near the sun's center the powerful force that causes the disturbance in the solar atmosphere is directed toward the earth and its influence should be felt on our planet which is relatively near the sun.

For many years astronomers have been observing the disturbances in the atmosphere of the sun and a record of sun-spots over a period of almost 200 years is now available. It is a well-known fact that the number of spots on the sun varies from time to time, with a well-marked period of about eleven and a third years. This same period seems to be associated with certain disturbances on the earth and scientists are wondering whether these are due directly to sun-spots, or whether both are the results of some external cause. However this may be, we are sure that there is a very close relation between the disturbances on the sun and on the earth.

There is no question but that magnetic and electrical disturbances on the earth are greatest at the time of a sun-spot maximum. A large spot is sometimes accompanied across the sun by a beautiful display of Aurora Borealis, or "Northern Lights," on the earth. This display is frequently visible at that time to people in the southern part of the United States and gives them an opportunity of seeing the Northern Lights when as a matter of fact they live too far south to have any right to see them. Scientists are now fairly well agreed that when a conspicuous spot appears approximately in line with the earth and the center of the sun, the ejected electrons strike the earth's atmosphere and cause electrification, which results in the auroral display.

SUN-SPOTS AFFECT RADIO RECEPTION

When the electrons are thrown from the sun into the atmosphere of the earth they not only furnish more "fuel" to the Aurora Borealis but they also cause many electrical disturbances of various kinds. In fact, a large spot never passes across the face of the sun without having its effect on the earth.

In February 1892 an enormous spot appeared on the sun and at the same time the Aurora Borealis was brilliant and frequent. In 1903 a gigantic group of sun-spots appeared and many magnetic and electrical disturbances were observed on the earth. Again in 1915 several giant groups of spots went across the face of the sun and the Aurora Borealis was especially noticeable. At this time there was much interference with telegraph, telephone and cable service. A large spot appeared in January 1926 and lasted through four rotation periods of the sun. At each appearance the spot produced a beautiful auroral display about twenty-four hours after it crossed the center of the sun's disc. The effect of this spot on the telephone, telegraph and cable was also very marked.

After the invention of radio it was only natural to raise the question as to whether the disturbances in the atmosphere of the sun had any effect on radio reception on the earth. Measurements of radio reception since 1926 seem to have established the fact that long-distance reception is poorest at the time of a sun-spot

maximum and best when there are only a few spots on the sun.

Dr. H. T. Stetson of the Perkins Observatory has recently made a careful study of sun-spots and radio and has come to the conclusion that solar disturbances affect radio reception by changing the elevation of the ionized layer of the earth's atmosphere—the "radio roof"—from which radio waves are reflected back to the earth. According to Dr. Stetson this so-called Heaviside Layer is lowered when large spots appear on the sun so that radio reception is bad—especially when the spots are near the sun's center—and it is lifted when the sun is quiet so that radio reception is good. If this is true, radio reception should be very bad in 1939, for there will be many spots on the sun that year. Dr. Stetson has also announced that radio intensity is affected to a certain extent by the moon, being much greater when our satellite is below the horizon.

SUN-SPOTS MAY AFFECT THE WEATHER

Do sun-spots determine our weather? This question cannot be answered in a satisfactory manner at the present time. It is obvious that if the sun should withdraw its heat from the earth, we would have no rainfall, no winds and no variation in temperature. In other words, if there were no sun there would be no weather. But the effect of the solar disturbances is not yet known, although this information might prove of much value in long-range weather forecasting.

An attempt was once made to show that sun-spots and warm weather come together and attention was called to the hot summers of 1846, 1857, 1868. This worked out beautifully and people were beginning to think that we would always have hot summers at the time of a sun-spot maximum, but in 1879 there was scarcely any summer at all. The average temperature of the surface of the earth seems to be somewhat cooler at the time of a sun-spot maximum and somewhat warmer than the average when there are very few spots on the sun.

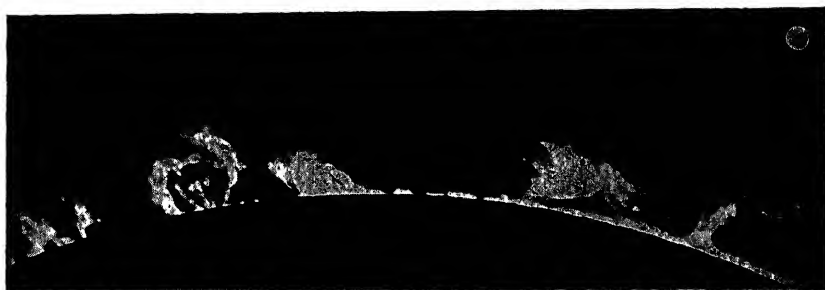
It is a well known fact that the width of the annual growth rings in trees varies with the number of sun-spots. Measurements of a pre-glacial spruce made recently from photographs reveal a

periodic variation of eleven years which corresponds very closely with the sun-spot period. Since this tree probably grew several thousand years ago these photographs bear witness to the fact that this sun-spot period has been constant for many centuries.

Some years ago scientists guessed that there was some relation between the level of the water in our lakes and the number of spots on the sun, and this interesting subject was recently carefully studied by Nassau and Koski. Lake Erie was chosen for this experiment because official reports are available showing the level of this lake from 1860 to date. By comparing the records of sun-spot activity and lake levels it was found that the dates of high and low water agree very closely with the years of sun-spot maximum, and also that two years after each sun-spot maximum the water was either at a high or a low level. Just how the disturbances on the sun can affect the level of water in our lakes is not yet evident, but it is obvious that there is some real connection.

FLAMES OF GAS SHOOT OUT FROM THE SUN

The most spectacular phenomena in connection with the sun are the solar prominences. There are two types of prominences—those that are quiet and those that are eruptive. The quiet prominences seem to be immense clouds which change their position very slowly and which are found on all parts of the sun's disc. Eruptive prominences are great flames of luminous gas that are projected outward from the limb of the sun thousands of miles



Arc of prominences showing current in opposite directions. A small circle shows size of earth in comparison with the sun.—Yerkes Observatory.

into space at a velocity sometimes of more than a hundred miles a second.

Eruptive prominences never appear except in the sun-spot zones and they seem to be very closely connected with the spots. When the spots are changing very rapidly the eruptions seem to shoot out with great rapidity but when the spots are quiet the prominences appear to float in the atmosphere of the sun like clouds. When there are many spots on the sun there will be found many prominences but when the spots are few the prominences as a rule are very scarce.

The prominences are in the chromosphere, or outer layer, of the sun and are usually invisible to the naked eye because of the dazzling light from the photosphere. During a total eclipse of the sun they are clearly visible around the edge of the moon's disk; however, it is no longer necessary to wait for a solar eclipse before we can study the prominences for the spectroscope will now reveal them at any time.

During a total solar eclipse the sun is surrounded by a beautiful halo of light which is called the corona. We know that this is not a reflection but that it is really a part of the sun because, as the eclipse progresses, we can actually see the moon pass over it. The corona is widest in the sun-spot zones, its total height being always at least two or three times as great as the apparent diameter of the moon. Although it is never visible except during a total eclipse, the existence of the corona has been known from remote antiquity.

Although the corona is really a part of the sun and not a mere optical phenomenon, it is composed of matter which is probably rarer than the best vacuum we can obtain under our air pumps. Upon a number of occasions comets have actually passed through the corona of the sun without having their motion disturbed in any way.

THE SCIENTIST KNOWS THE COMPOSITION OF THE HEAVENLY BODIES

One of the most interesting questions in connection with the sun has to do with its chemical composition. What is the sun

composed of? In 1823 the great French philosopher Comte declared that there was at least one thing man could never know—the chemical composition of the celestial bodies. In less than forty years this was made possible by the invention of the spectroscope.

Galileo invented the telescope in 1610 and man's ideas about his universe were completely changed. The more he improved his telescope the more clearly were the secrets of nature revealed to him until he began to feel that his knowledge of his universe was limited only by the size of his telescope. As a matter of fact the discoveries of modern astronomy have been due in a large measure to an instrument of a different type—the spectroscope. We will not take time here to explain the workings of the spectroscope. Suffice it is to say that the spectroscope enables us to study the light that comes from far distant objects, to determine therefrom their chemical composition, their physical condition, and to measure the speed with which they are moving either toward us or from us.

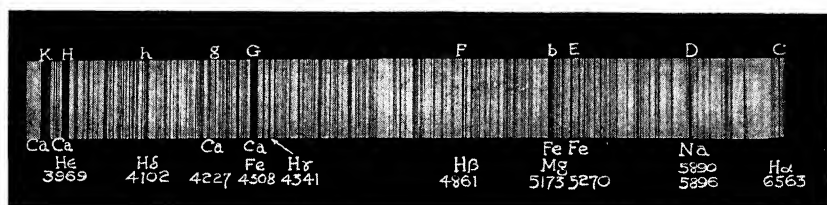
Sir Isaac Newton seems to have been the first scientist to call attention to the fact that a ray of white light from the sun was really composed of rays of different colors. This study was continued by his successors and after the invention of the spectroscope in 1860 the study of spectrum analysis began in earnest. We can now tell the chemical composition of any heavenly body which is bright enough to be seen through the spectroscope. This applies to the sun, to the comets, to the nebulas, and to all of the stars. Thus the writer of that jingle, "Twinkle, twinkle, little star, how I wonder what you are," would be somewhat out of date today. We now know what they are.

Most stars are so far from the earth that their light reaches us hundreds and even thousands of years after it has been radiated into space. This enormous distance, however, makes no difference to the astronomer. If the light is strong enough to register in his spectroscope he analyzes it just the same, realizing of course that he is studying the chemical composition of the star as it was before the young Moses was hidden on the banks of the Nile.

THE SUN CONTAINS THE SAME CHEMICAL ELEMENTS AS THE EARTH

When we examine a celestial body with the spectroscope we do not see an image of the body but merely a ribbon of light which we call a spectrum. The spectrum exhibits all of the colors of the rainbow in this order—red, orange, yellow, green, blue, indigo, violet. If you have trouble remembering the colors of the rainbow just keep in mind the name of my imaginary friend, Mr. Roy G. Biv (R-O-Y G. B-I-V).

The colors in the spectrum are of no importance and we pay no more attention to them than to the colors in our maps when we are studying geography. We are concerned with the lines which cross the spectrum like the pickets on a fence. The existence of one or more lines at given distances from one end of the spectrum means that there is a certain chemical element in the sun. If no such lines appear then this element is not to be found on the sun. This sounds very simple and it was indeed a very remarkable discovery. It was not until two hundred years after Newton in 1666 first passed sunlight through a glass prism and broke it up into its fundamental colors that G. R. Kirchhoff announced the principles of spectrum analysis, but since that time progress along this line has been very rapid.



The visual solar spectrum.—Yerkes Observatory.

Sometimes all of the lines shift slightly toward one end of the spectrum and again they shift toward the other end. If this shift is toward the red end of the spectrum we know that the heavenly body which is being examined is moving away from the earth. If the shift is toward the violet end the body is coming toward us. We can measure the amount of the shift and tell how fast the body is moving in our direction, either toward us or from us.

Thus you see that the spectroscope not only reveals the composition of the sun, or of any star, but it also tells us how fast the sun or star is moving and in what direction.

The study of the sun and other heavenly bodies by means of the spectroscope has led us to the remarkable discovery that everything in the visible universe—sun, moon, stars, planets, trees, rocks, machines and human beings—is made of the same material. Indeed this was to be expected but it is only recently that proof has been possible.

HELIUM WAS DISCOVERED ON THE SUN AND LATER FOUND ON THE EARTH

One by one the chemical elements on the sun have been identified with the corresponding element on the earth until today we have found on the sun and in its atmosphere fifty of the ninety-two chemical elements with which we are acquainted. Because of the terrific heat of the sun most of the elements in its atmosphere are found in the atomic state although a few of them occur in compounds. The most abundant element is hydrogen but considerable quantities of oxygen, helium, and even some of the metals, such as iron and magnesium, are found.

The identification of the different chemical elements on the sun is very interesting from a scientific point of view but the most fascinating chapter in the study of the chemistry of the sun might well be called *The Romance of Helium*. When a trace of an element appears in the spectrum of the sun it is usually fairly easy to identify this element. However, the chemical element which was responsible for a certain bright yellow line in the solar spectrum could not at first be identified with any element with which the people on the earth were familiar. This element was called Helium from the Greek word *Helios* which means "sun."

For twenty-seven years our chemists were forced to admit that there was an element on the sun which, as far as they knew, did not exist on the earth. Finally in 1895 the great English scientist, Sir William Ramsey, found helium in the atmosphere of the earth. Thus this element enjoys the distinction of having been discovered on the sun 93 million miles away before it was found

on the earth beneath our feet. It is a remarkable fact that this light, non-inflammable gas which plays such an important part in the operation of lighter-than-air machines was discovered in rather large quantities in the United States during the World War, just at the time when it was needed. The United States now produces millions of cubic feet of helium annually.

During the eclipse of 1869 Professor William Harkness of the Naval Observatory discovered some bright lines in the spectrum of the corona of the sun, indicating the presence of some element with which he was not acquainted. Up to the present time this element, which was called coronium, has not been identified with any element on the earth.

CORONIUM MAY RESULT FROM HYDROGEN

While astronomers were trying to identify coronium and nebulium—the new “element” apparently present in certain nebulae—scientists began to explore the hitherto “indivisible” atom and discovered that every atom is a solar system in miniature—a central nucleus with one or more revolving electrons. One by one the different chemical elements were identified with the numbers 1, 2, 3—up to 92, inclusive, and the list of elements seems now to be complete, beginning with hydrogen with one revolving electron and ending with uranium with 92 revolving electrons.

This apparently complete list of elements contains helium—with its two revolving electrons and corresponding to the number 2—but there seems to be no place in this scale for the “foreign” elements coronium and nebulium. This naturally raised a serious question as to the actual existence of these hypothetical elements and made scientists even more determined to pursue this investigation further.

Several years ago astronomers came to the conclusion that there was no such element as nebulium, but that this strange light must be directly attributed to oxygen and nitrogen in a highly ionized condition. The number of extra-terrestrial chemical elements was thus further reduced from two to one—coronium. It has been suspected for some time that the green lines in

the spectrum of the corona of the sun were in some way due to oxygen, but these lines have been visible only during the fleeting moments of total eclipses and consequently the verification of these suspicions has been exceedingly slow. It now seems that the mystery as to why the hypothetical element coronium does not appear in our apparently complete list of 92 elements will soon be solved after this elusive element has escaped identification for almost 70 years.

After a study of the light given off by the Nova that recently appeared in the constellation Ophiuchus, the astronomers both at Harvard Observatory and at Mt. Wilson in California have announced the identification of some of the bright lines in the sun's corona with oxygen. It seems that the oxygen in the atmosphere of this exploding star does not behave as it does under ordinary conditions. Thus it appears that, as in the case of nebulium, the mysterious element coronium is nothing but the life-giving element oxygen, which is unable to behave naturally when situated in the corona of the sun or in the atmosphere of an exploding star.

THE SUN'S TEMPERATURE IS AT LEAST TEN THOUSAND DEGREES

It is indeed quite impossible to appreciate the expenditure of heat and light from the sun, which is apparently being wasted because we seem to have no way in which we can make use of it. If we judge the temperature of the sun by the heat which we receive on the earth at a distance of 93 million miles we are forced to the conclusion that the sun is actually hotter than anything we can imagine. Every square yard of the surface of the earth receives from the sun one and one-half horse power of energy. In fact, there is enough heat falling on the deck of a ship in tropical latitudes to propel it at a speed of about ten knots per hour without making use of any other motive power if we could only find some way to harness this energy. The average amount of solar heat which falls on every square foot of the earth's surface would raise 100 tons to the height of almost a mile if we could only utilize it in a perfect heat engine. On every

square mile the sun generates 646,000 horse power of energy so that, if we could only harness the sun, we would need no other source of energy.

Many of us have perhaps wondered at the heat generated in the modern blast furnace where even steel can be melted into a liquid. Let us imagine the temperature of that liquid multiplied many times and we shall then obtain some idea of the intensity of the heat which is radiated from our celestial furnace. The temperature of the sun is at least 10,000° Fahrenheit.

At the California Institute of Technology an attempt is being made to duplicate the heat of the sun. By means of about 40 lenses it is hoped to reduce the diameter of a large beam of sunlight from ten feet to a small fraction of an inch and in this way attain a temperature as high as that of the sun.

Dr. Abbot of the Smithsonian Institution recently made the interesting announcement that our weather appears to be governed by variations in solar radiation. For the last twenty years Dr. Abbot has devoted much time to the study of solar radiation and has discovered variations in the heat of the sun extending over many months. This seems to be the first step toward weather forecasting over long periods.

MANY THEORIES ATTEMPT TO ACCOUNT FOR THE SUN'S HEAT

For countless ages the sun has been radiating heat and light in every direction. For hundreds of millions of years it has been pouring out the same flood of energy as at present. Since the sun does not appear to be cooling off we naturally wonder how this enormous supply of heat is maintained.

This question is somewhat difficult to answer but we can say that the sun is not merely a hot body just cooling off. If the sun were made of anthracite coal, it would be burned to a cinder in less than three thousand years. It has been suggested that this heat may be maintained by the friction resulting from meteors falling into the sun. However, if meteors were falling into the sun fast enough to maintain its heat the air in the vicinity of the

earth would be thick with them and the earth would be red hot from their impacts. In fact, so much meteoric matter would be demanded that it would change the motions of the planets.

A theory generally accepted until about 1920 was proposed by Helmholtz in 1854, who stated that an annual shrinkage of three hundred feet in its diameter would liberate enough heat to keep the sun at its present temperature. In other words, the sun maintains its heat simply by contracting. Why do not astronomers measure the sun at the beginning and at the end of a year and tell us whether it is shrinking at this rate? A shrinkage of 300 feet per year would amount to one mile in about 18 years and almost 8,000 years would have to elapse before the shrinkage would be enough to be detected by the most powerful telescope of the present day.

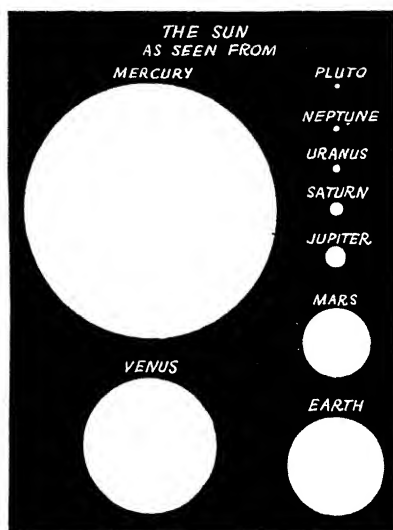
If we accept the theory that the sun's heat is maintained by the gradual shrinkage of its volume which must have been much more rapid in its early stages than at present, we must admit that the sun would have shrunk to its present size in about 25 million years. Since the earth has been in existence about one billion years many scientists have abandoned this theory.

Scientists today are devoting much time and study to the question as to how the heat of the sun is maintained and their results seem to indicate that its heat may be attributed to the energy that is liberated in the transformation of atoms.

THE SOLAR SYSTEM IS MERELY A GRAIN OF SAND IN THE UNIVERSE

No matter what may be the answer to the question as to the maintenance of the sun's heat it is fairly obvious that the sun can not last forever. It has been estimated that it still contains enough energy to maintain life on the earth for thousands of millions of years. Of course after the expiration of this period of time so great a change may have taken place on the earth that people who are here at that time may not need as much heat as we require, so that life of some kind may go on here for a much longer period.

We usually think of the sun as the dominant member of the solar system and look with fearful admiration at that heavenly body which controls all of our motions, furnishes us light and heat, and actually keeps us alive. Let us now consider the sun from another point of view. You will learn when you come to the study of the stars that the sun is nothing but a star and a very small star at that. The sun appears large to us merely because we are close to it but many stars exceed it both in brightness and



If we should move to the outskirts of the solar system the sun would assume the appearance of a small star.

in volume. Not only is the sun a star but, just as other stars are moving, so also is the sun moving apparently in a straight line toward a point in the sky which is not very far from the bright blue star, Vega.

In the early days man believed that his little earth was the center of the universe, and he was very much disturbed when he discovered that his world and several others were revolving around a central sun. Hardly had the human race settled down to life on a little world revolving around what was supposed to be a fixed sun until the announcement was made that this sun with its retinue of planets, moons, comets and meteors is sailing through space with a velocity of more than twelve miles per second. When

we think about the sun with nine planets whirling about it, which we have looked upon as a gigantic machine and which we have regarded as so important in the celestial landscape, and discover unexpectedly that the entire solar system is just a mere fly speck in the universe, we exclaim with Job, "Lo, these are parts of His ways, but the thunder of His power who can understand."

CHAPTER III

Other Worlds Than Ours

THE HIGH SPEED OF MERCURY IS RESPONSIBLE FOR ITS NAME

THE fact that the little planet Mercury is so hard to catch with the eye, flitting back and forth from one side of the sun to the other, and moving so fast that it breaks the speed limit in the solar system, is responsible for its name. If you will recall some of the beautiful stories and legends which you learned from classical mythology, you will remember that Mercury was the son of Jupiter and that he served as special messenger of the gods. When he was not busy with these errands he was supposed to watch over thieves and robbers and all dishonest persons. He also conducted the souls of the dead to the gates of Hades. To Mercury was assigned the duty of conducting Proserpina, the goddess of vegetation, back and forth from Hades to the earth every six months so that the grass might grow, the birds sing, and the flowers bloom.

Not only was Mercury a swift and reliable messenger but he was also a genius. Before he was one day old he sprang from his mother's knee, picked up a turtle shell which was lying on the ground and, having stretched strings across it, invented the first lyre. However, he was not allowed to keep his musical instrument very long for he was forced to give it to Apollo in payment for some oxen which he stole later in the day.

Mercury was always so full of mischief that he was a great favorite with the other gods. His father, Jupiter, gave him a sword, a winged cap and some winged shoes. This made it possible for him to move very swiftly and gratify all of Jupiter's wishes. Apollo was so pleased with the lyre which Mercury had invented and presented to him that he gave Mercury a magic wand which had the power of restoring peace and quiet to con-

flicting elements. Mercury was naturally very anxious to test this wand and threw it between two snakes who were engaged in a mortal combat. The snakes immediately ceased their fighting and curled themselves around it. Mercury then forced the snakes to remain there forever and he carried the wand with him on all occasions.

What better name could have been selected for the little world that remains in hiding most of the time, appearing suddenly here today and there tomorrow, than Mercury—the mischievous little swift-moving messenger of the gods?

MERCURY IS SO CLOSE TO THE SUN THAT IT IS VERY SELDOM SEEN

From time to time people have wondered whether there might be a planet between the sun and Mercury. In fact, such a planet was announced in 1859 and was even given a name, Vulcan. What better name could be found for this tiny world, which apparently existed almost within reach of the flames from the sun, than Vulcan—the god of fire and of the forge. Again in 1878, this same announcement was made but recent observations have convinced the astronomers that Vulcan does not exist.

Many people become interested in the planet Mercury because it is so difficult to see. This planet never gets very far from the sun and consequently it must be observed very soon after sunset or before sunrise if it is to be seen at all. It is usually completely lost in the brilliant light of the sun's rays and goes down below the horizon before it becomes dark enough for us to see it. Our curiosity is naturally aroused by a world which remains hidden most of the time and many people are wanting to know more about Mercury.

Recorded observations of Mercury go back to 264 B. C. The planet was not recognized by the Greek scientists as the same body when east of the sun as when west of the sun. They called it Apollo when it was morning star and Mercury when it was evening star. Mercury is invisible most of the time. In fact, Copernicus, the celebrated astronomer, is said never to have seen it.

The amount of heat received from the sun per square mile on two planets varies inversely as the squares of their distances from

the sun. In the case of Mercury we find that every square mile of its surface receives about seven times as much heat on the average as the same area on the earth, so that it would probably be rather uncomfortable for us if we should try to live on that world. Since Mercury is much closer to the sun at some times than at others, the amount of heat falling on the planet varies from time to time. In fact, when Mercury is closest to the sun it receives two and one-half times as much heat as when it is farthest away. In six weeks the sun would increase to more than twice its apparent size if observed by someone living on that planet. This alone would be sufficient to cause seasons on the planet.

MERCURY EXHIBITS ALL THE PHASES OF THE MOON

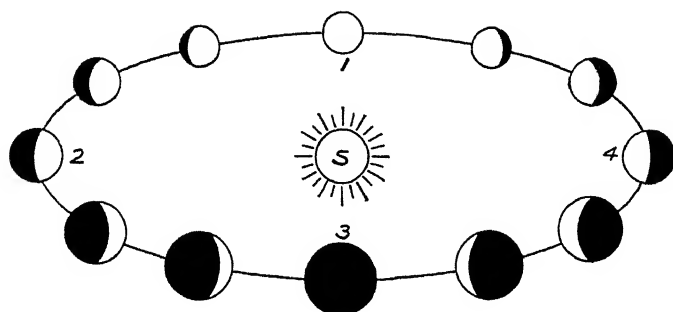
Although the little planet Mercury has been known from remote antiquity and is sometimes brighter than any star, except Sirius, it is so difficult to observe that less is probably known about it than about any other planet. When we compare it, however, with the other planets we find that it is an exceptional world in seven different ways: it is the smallest world, it has the least mass of any world, it is nearest the sun, it receives the most light and heat, it moves fastest, it has the flattest orbit, and it has the greatest inclination to the plane of the earth's orbit.

The diameter of Mercury is about 3000 miles, which is only 38% of the diameter of the earth. Since the areas of two spheres vary as the squares of their diameters, the area of its surface is only about 15% of that of the earth. In other words, there is less than one-seventh as much surface on Mercury as there is on the earth. The density of Mercury is about 70%, and its surface gravity about 27%, of that of the earth. If we should attempt to deliver a ton of coal to Mercury, its weight would shrink to 540 pounds and the driver would probably not weigh 50 pounds.

All of the planets move about the sun in ellipses, which are merely flattened circles, with the sun slightly out of the center. These ellipses, however, differ so little from circles that if the orbits should be carefully drawn the oblateness could scarcely

be detected except in the case of Mercury, where the sun is quite a bit out of the center.

Mercury exhibits phases (crescent, full and half) just like the moon does as seen from the earth. This is due to the fact that Mercury gives no light of its own, but shines merely by reflected light. We see only that part of Mercury upon which the sun happens to be shining at that time and, since the relative positions



PHASES OF MERCURY

of the sun, the earth and Mercury change from time to time, Mercury must exhibit phases as seen from the earth.

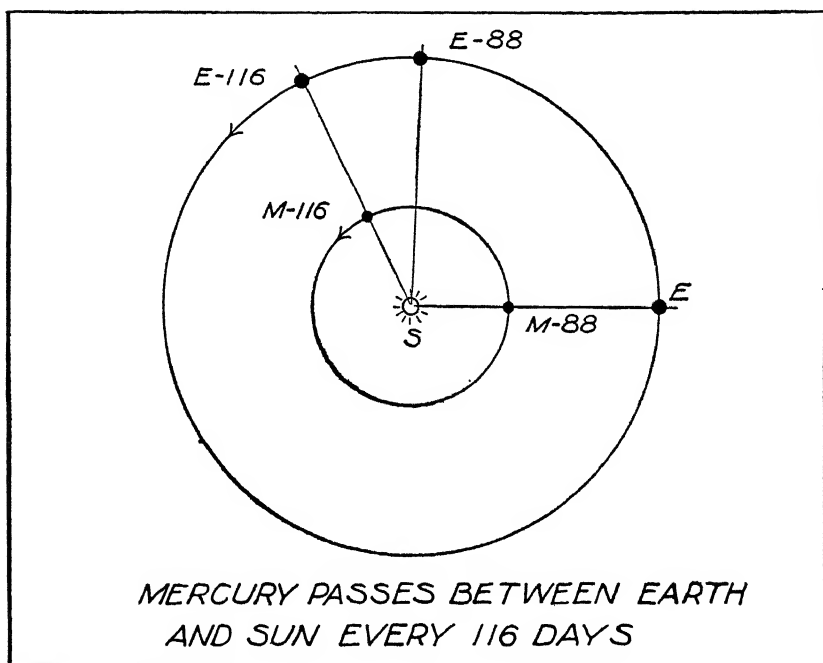
The atmosphere of Mercury must be very rare. In fact, some authorities believe that it is entirely absent. Under the action of solar heat a planet as small as Mercury would probably lose its atmosphere very rapidly. Although much time has been devoted to the study of this planet we have no satisfactory maps of its surface.

THE DEAD PLANET MERCURY OUTFRONS ITS COMPANION WORLDS

When the sun pours its heat upon the earth on a hot August day we are thankful that nature has placed us 93 million miles from that celestial furnace and we would not care to move any closer. The inhabitants of Mercury, if there be any, are not so fortunate for the average distance of that world from the sun is only about 36 million miles. Furthermore, the sun is so far out of the center of the orbit that this distance is sometimes reduced

to 28 million miles. At this distance the amount of solar heat falling upon a square yard of Mercury's surface would be almost eleven times as great as that which falls upon an equal area on the earth.

Mercury is the swiftest moving world, its velocity varying from 36 miles per second when closest to the sun to 24 miles per



Suppose Mercury and Earth are in line with Sun. After eighty-eight days Mercury will be back to the position M-88, but the earth will then be at E-88, and twenty-eight more days must pass before Mercury gets back in line.

second when farthest away. It moves around the sun so rapidly that it makes a complete circuit in 88 days. In other words, a year on Mercury is only 88 of our days. This is known as the sidereal period of Mercury, or its period as determined by the stars.

Although Mercury makes one complete trip around the sun every 88 days the earth is also moving around the sun in the same direction so that, after Mercury has completed its circuit, it will be several days before it overtakes the earth. In fact 28 extra days are necessary to allow Mercury to catch up with the earth, so that the planet passes between us and the sun every 116

days. This is known as the synodic period of the planet. Thus, if Mercury is evening star now it will be in about the same position at sunset 116 days from now.

The rotation period of Mercury seems to be equal to its sideral period of 88 days. That is, it rotates once in each revolution, keeping the same face toward the sun all the time. One side of the planet is intensely cold and never exposed to the rays of the sun; the other side is intensely hot and probably burned to a cinder. For an observer on Mercury there would be no succession of day and night for the sun would not rise and set. It would probably have a slight oscillatory movement due to the variation in the velocity of Mercury around the sun.

MERCURY SOMETIMES FLITS ACROSS THE FACE OF THE SUN

On account of the fact that Mercury is very close to the sun and is moving around it very rapidly the planet appears to oscillate from one side of the sun to the other as observed from the earth. Of course Mercury cannot be seen in the day time on account of the glare of the sun. When it is west of the sun it will disappear below the horizon before sunset and reappear in the east at dawn as Morning Star, and when it is east of the sun it will be above the horizon at sunset and it may be visible in the twilight as Evening Star. Its greatest distance east (or west) of the sun is never more than 28 degrees and it reaches this greatest eastern (or western) elongation once every 116 days. This is the best time to look for the planet.

If the sun is far enough below the horizon for it to be dark enough to see the planet, Mercury will be very low in the sky and, therefore, rather difficult to observe, but if you have an unobstructed view of the horizon you should be able to find it. After you have discovered this elusive little world you will have the satisfaction of knowing that, although Copernicus made many contributions to the science of astronomy and persuaded the people to give up the erroneous ideas of Ptolemy, he never had the pleasure of looking at this planet.

It sometimes happens that as Mercury goes between us and the sun it actually passes across the face of the sun. Since the

planet is so small in comparison with the sun it is not visible to the naked eye while in transit. But if you watch a transit of Mercury through a telescope, you will see the planet as a black spot upon the face of the sun without any encircling rings of light. This means that Mercury has no atmosphere.

The first transit of Mercury that was ever predicted was announced by Kepler in 1629, who stated that on November 7, 1631, a transit of Mercury would occur. This transit actually occurred only five hours after the time predicted by Kepler. This was the first transit ever observed and was indeed a remarkable prediction for that time. Transits of Mercury can occur only in May and November. The last transit was on May 7, 1924, and Dr. F. R. Moulton promises us another one on May 10, 1937.

THE BEAUTY OF THE PLANET VENUS ACCOUNTS FOR ITS NAME

Since early man seems to have been determined to associate the planets with the gods and goddesses which classical mythology placed upon Mount Olympus, it was but natural for him to name the most beautiful planet after the most beautiful goddess, just as the largest planet was named Jupiter after the king of the gods, and the red planet was called Mars after the god of war. The planet Venus which is the brightest and most conspicuous heavenly body, with the exception of the sun and the moon, and which is sometimes easily seen in the day time carries the name of Venus, the goddess of beauty. This goddess was supposed to have sprung from the foam of the sea and was the impersonation of beauty, love, laughter and marriage. She was always attended by many beautiful nymphs and Love and Desire were her constant companions.

The child Venus was first discovered by the ocean nymphs floating on the crest of a great blue wave. They carried her down into their coral caves where, under their tender care, the child soon developed into a woman of marvelous beauty. She then went with her companions to Mount Olympus where she was presented to the gods there assembled. Her beauty took them by storm, for never before had the eyes of gods or men ever gazed upon such a beautiful woman.

Each god in turn made her a proposal of marriage but she would listen to none of them, not even to the king of the gods. When Jupiter's offer was declined he became so angry that he decreed that Venus, the most beautiful woman in the entire universe, should be married to Vulcan, the lame and deformed god of the forge. It goes without saying that Venus did not remain faithful to Vulcan very long, deserting him for Mars, the valiant god of war. Venus and Mars had several children, perhaps the most famous of whom was Cupid, sometimes called Eros, the little god of love.

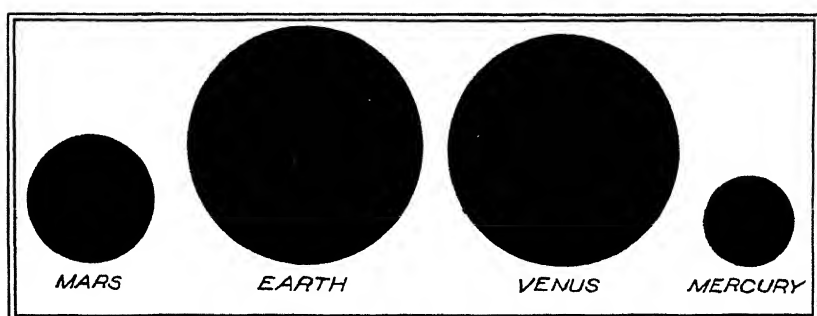
Among the tribes of northern Europe the goddess of love and her husband, the war-god, were worshipped under the names of Frija and Tius. The Scandinavians later called her Frida, from which our word Friday has been derived. Frija was known among the Greeks as Aphrodite, but the name most familiar to us is Venus, as she was called by the Roman people.

VENUS IS THE TWIN SISTER OF THE EARTH

As we look with admiration at the brilliant planet Venus we must remember that we are looking at the twin sister of the earth. Venus is not a tiny world, like Mercury. Its diameter is only about three hundred miles less than that of the world on which we live. In fact, for every 100 square miles on the surface of the earth there are 95 square miles on the surface of Venus. Its density is about the same as that of the earth and its general constitution and physical condition are more like those of the earth than any other planet. Surface gravity on Venus is about 85 % of that on the earth. A ton of coal would weigh 1700 pounds if it were delivered on the planet Venus. We sometimes wonder whether some of our own coal dealers do not imagine that they are living on this beautiful planet.

The orbit of Venus, like that of Mercury, is inside of the orbit of the earth. On account of its motion around the sun Venus is sometimes Morning Star and sometimes Evening Star. This fact was not known to the Greeks and for this reason the planet was called Phosphorus when west of the sun and Hesperus when east of the sun.

Venus makes a complete circuit of the sun in 225 of our days, but in the meantime the earth has moved forward in its orbit about 225 degrees. Thus, if the sun, Venus and the earth are in a certain relative position today, they will not get back into this same position again at the end of 225 days because Venus will require several days to catch up with the earth. In fact Venus will



Venus is the twin sister of the earth.

not catch up until 584 days have passed. In other words, if Venus is Morning Star now at her greatest elongation west of the sun she will be back in that same position in 584 days, which is the synodic period of the planet. We must not confuse these two periods of time. If there were anybody living on Venus they would say that their year was up in 225 of our days because they make a complete circuit around the sun while the earth rotates 225 times. However, as observed from the earth, Venus will not get back into the same position with reference to the sun for 584 days.

OUR NEAREST WORLD IS VENUS

Venus is going around the sun inside of the orbit of the earth so that our distance from that planet varies from time to time. When Venus is between the earth and the sun it is only about 26 million miles from us, but when it is on the opposite side of the sun its distance from the earth is more than 160 million miles. In other words, it is about six and one-half times as far from the earth at one time as at another time so that the brightness of the planet varies from time to time. When Venus is closest to us it is

very bright and it even casts a shadow on a piece of white paper. (This shadow could be easily seen at its favorable appearance in March, 1929.) When viewed through a telescope at this time Venus is a beautiful crescent.

As in the case of Mercury, it sometimes happens that Venus gets between us and the sun so that it actually crosses the face of the sun. These transits of Venus occur in pairs and are very rare. According to Dr. Moulton the next pair will occur on June 8, 2004, and on June 5, 2012. During a transit Venus is surrounded by a beautiful ring of light which is due to its atmosphere. Transits of Venus can occur only in June and December.

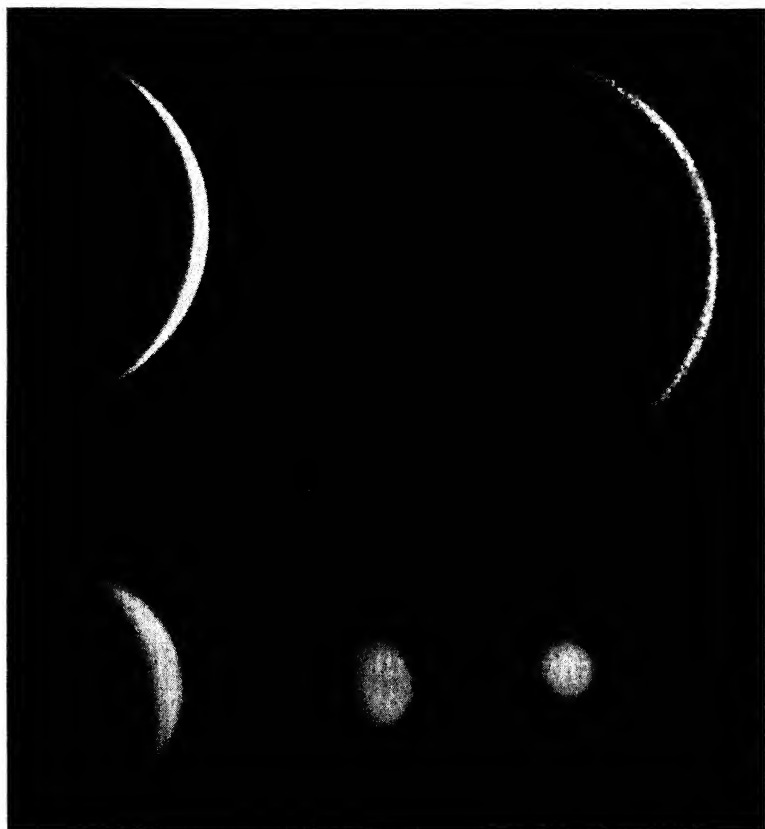
In order that we may appreciate the great distance which separates the earth from Venus even when the two planets are closest together, we need only call attention to the fact that an express train traveling at the rate of a mile a minute day and night without stopping would require fifty years to make the trip from the earth to Venus. If Lindbergh should decide to hop off the earth on a non-stop flight to Venus he must first make adequate preparation for a long flight for, if he should fly at the rate of 200 miles an hour, he must spend fifteen years on the trip, even when the planet is closest to us.

A ray of light, which travels seven times around the earth in one second, would require more than two minutes to make this same trip. That is, when you look at Venus you see it, not where it actually is, but where it was several minutes before. No wonder this planet, which is almost as large as the earth, looks rather small in comparison with our world.

VENUS SHOWS ALL THE PHASES OF THE MOON

The great variation in the distance of Venus from the earth causes that planet to appear much more brilliant at some times than at others, but there is another reason why the earth's twin sister varies in brightness. We must remember that Venus gives no light of its own but shines only by reflecting the light of the sun. As the planet moves around the sun in its almost circular orbit, with a velocity of about 22 miles per second, only that part of its surface which faces the sun is illuminated, the back side being buried in the shadow of the planet.

Because of its varying position with reference to the sun we sometimes see all of the "daylight" side of the planet, sometimes a part of it and sometimes none, so that Venus will exhibit all the phases of the moon. When it is closest to us it is largest



Photographs of Venus by E. C. Slipher at Lowell Observatory.

and has the appearance of a long, thin crescent. When it is farthest away it is very much smaller, but it looks like the full moon. The phases of Venus cannot be seen with the naked eye, but they are visible through a very small opera glass.

When Galileo looked through his little telescope in 1610 and announced that "the mother of loves (Venus) imitates the phases of Cynthia (Moon)," most thinking people were ready to give up the old incorrect ideas of Ptolemy and Aristotle and accept the theories of Copernicus. The fact that the earth was reflecting the light of the sun to the moon and that Venus also

was shining with the reflected light of the sun, was very convincing evidence that the earth was very similar to the other planets and that they were all revolving around the sun and making use of the light which was being radiated by that heavenly body.

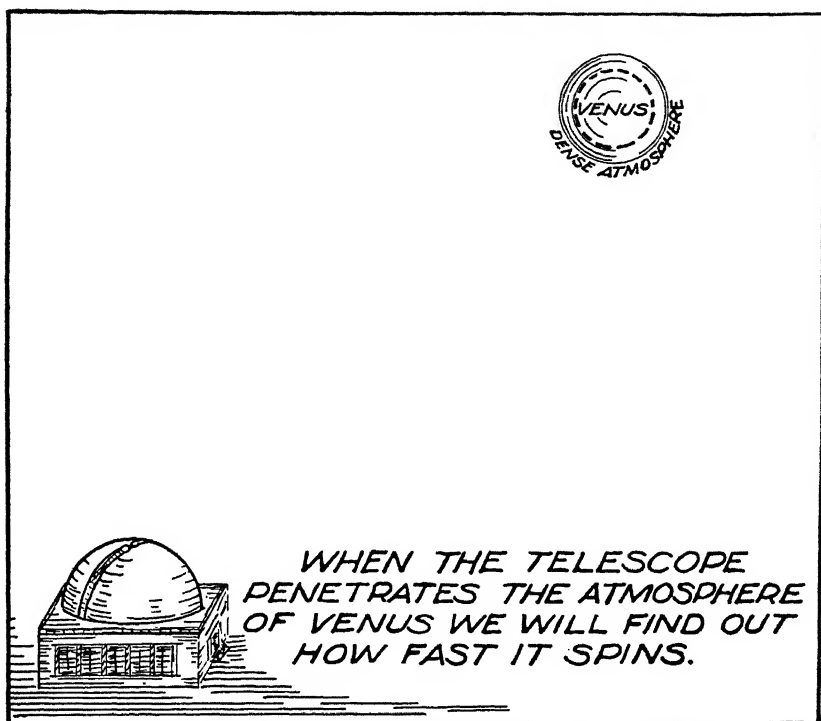
If all of the planets, including Venus, were revolving around the earth, as early peoples believed, Venus would not exhibit all of the phases of the moon. It is indeed too bad that ancient peoples did not have telescopes so that they might have been prevented from falling into this error. Much time would have been saved which might have been devoted to other scientific investigations. The theory that the earth was the center of the universe became so firmly fixed in the minds of people that it was not overthrown for about fourteen centuries.

THE LENGTH OF THE DAY ON VENUS HAS NOT YET BEEN DETERMINED

Although much is known about Venus, the length of its rotation period has not yet been determined. Mercury has no atmosphere and its rotation period may be very accurately determined by observation of the fixed markings on its surface, but Venus has an atmosphere which even our largest telescopes have not yet been able to penetrate. This atmosphere, like our own, may serve a very useful purpose but it makes very difficult the problem of determining the rotation period of Venus, with no permanent surface markings to guide us.

It was at one time thought that Venus rotates on its axis with a period of approximately twenty-four hours as in the case of the earth. However, the earth and all of the other planets with short rotation periods are flattened at the poles, the oblateness being greatest in the case of those that rotate fastest. Careful measurements fail to reveal any difference in the polar and equatorial diameters of Venus so that the planet probably has a rather long period of rotation. In fact there is some evidence that the planet keeps the same face toward the sun all of the time just as Mercury does. In other words, that it rotates once in a period of 225 days.

If it should be finally determined that the length of the day on Venus is approximately the same as that on the earth, those who argue that Venus is inhabited by living beings similar to



those on the earth would be in a much stronger position. However, even if the length of the day turns out to be 225 of our days, life might still exist on Venus, although it would probably be different from human life here on the earth.

After the discovery of the two moons of Mars which are so close to its surface that they are very difficult to observe, the question arose as to whether Venus might also have one or more satellites. A small moon very close to the surface of Venus would be extremely hard to discover on account of the brilliance of the planet and its nearness to the sun. Venus has been carefully studied and photographed during several eclipses of the sun so that, if such a satellite exists, it would probably have already been discovered. We are, therefore, forced to the conclusion that Venus, like Mercury, probably has no attendants.

THE COLOR OF MARS IS RESPONSIBLE FOR ITS NAME

The planet Mars, like Mercury and Venus, has been known since pre-historic times. The variations in its color and brightness must have attracted the attention of the earliest observers. This planet is very favorably situated for observation from the earth and more is probably known about Mars than any other planet. I trust that, after I have finished telling you about this planet, you will know more about it than the high school boy who, when asked, "What is Mars?" answered, "Mars is the scratches you get on the parlor furniture."

Mercury was named after the messenger of the gods because of its swift motion. Venus, the brightest planet in the entire sky, was named after the goddess of love and beauty. The ruddy planet Mars owes its name to its color which makes it very conspicuous among the planets.

Long before the wandering tribes of Europe had attained any degree of civilization our nomadic ancestors worshipped Tius, the one-armed god of war, who not only showed them how to make tools and weapons but also constantly exhibited the effects of hard fighting by his many scars and his missing arm. After these tribes separated and formed distinct nations their language gradually changed and we naturally find the war-god called by different names in different countries. Among the Scandinavians Tius became Tiesco from which our word Tuesday is derived. The Greeks called this same god Ares and the Romans chose to call him Mars, from which comes our word "martial."

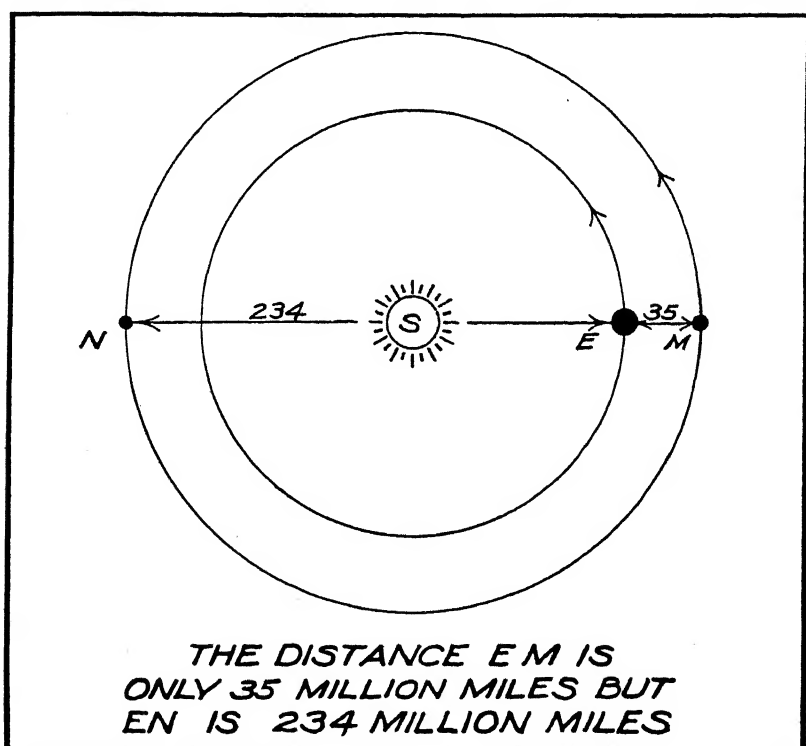
Mars, the god of war, was the son of Jupiter and Juno and was one of the principal Roman gods. This was very natural since the Romans were frequently engaged in war. Many of the Roman soldiers believed that Mars actually marched in person at the head of their army and brought them victory. Surely there could be found no better name for that red planet than Mars, which signifies war and bloodshed.

Mars is much smaller than the earth, having a diameter of only 4200 miles, which is only about 53 per cent of the diameter of the earth. Its area is about two sevenths, and its volume one seventh that of the earth. Surface gravity on Mars is only about

38 per cent of that of the earth, so that, if you weigh 150 pounds on the earth you would weigh only 57 pounds on Mars.

MARS HAS A DAY ABOUT EQUAL TO OURS

Since the orbit of the earth is inside of the orbit of Mars it is obvious that the planet will be much closer to us when we are both on the same side of the sun than it is when the earth is on one side of the sun and Mars on the other side. In fact, Mars may come within 35 million miles of the earth. On the other hand it may get as far as 234 million miles from us. Consequently this



planet will vary in brightness and apparent size from time to time. Although Mars is one of our closest neighbors it never gets close enough to us for an airplane to make the trip between the two planets in less than twenty years, flying at the rate of 200 miles per hour.

The atmosphere of Mars is not very dense so that it is possible to actually see its surface and to identify certain very distinct surface markings. A study of these permanent features makes it possible to determine its rotation period with great accuracy. The length of the day on Mars is 24 hours, 37 minutes, 22½ seconds, so that the inhabitants of that planet have a day which is almost the same length as ours. It is very interesting to study this planet through a large telescope and to watch it rotate on its axis.

The year on the planet Mars is about 687 of our days, so that the seasons on that planet are almost twice as long as they are on the earth. The angle between the equator of Mars and the ecliptic is about 25 degrees. When you recall that seasons on the earth are due to the fact that the equator of the earth makes an angle of about 23 degrees with the ecliptic you are forced to the conclusion that the seasons on Mars must be very similar to those on the earth, although they are much longer.

The surface of Mars must be divided by nature into five zones similar to those on the earth. The Arctic Zones must extend 25 degrees from the two poles and the Torrid Zone must be 50 degrees wide, extending 25 degrees on each side of the Martian equator. The North and South Temperate Zones occupy the remaining area of the planet, extending from latitude 25 degrees up to latitude 65 degrees.

THE CANALS ON MARS MAY HAVE BEEN BUILT BY HUMAN BEINGS

The behavior of the white polar caps of Mars seems to indicate the presence of an atmosphere on that planet. Recent researches by means of the spectroscope and photography have convinced most astronomers that Mars has an atmosphere which is much less dense than our own. This is to be expected since Mars is so much smaller than the earth.

In the latter part of the nineteenth century, Dr. Percival Lowell became very much interested in the study of Mars. In 1894 he built an observatory at Flagstaff, Arizona, and, with an able staff of assistants, began the systematic study of the planet

to which he had dedicated himself and his fortune. At his death in 1916 he left an endowment to carry on the work of the Lowell observatory and several hundred canals and oases of Mars have been mapped by the workers at Flagstaff. The canals of Mars were first discovered by the astronomer Schiaparelli in Italy, but the task of exploring and naming these markings was left to Dr. Lowell and his staff.

Some people are of the opinion that the markings on Mars are canals which have been constructed by intelligent human beings. There seems to be no good reason why human beings could not live on Mars. This planet is probably at a rather advanced period in its evolution and much of its surface is desert waste. We would probably find on Mars a higher state of civilization than on the earth, but the inhabitants, like the planet, have probably passed their zenith and are on the decline.

The question is frequently raised as to whether it will ever be possible to send signals to Mars. How much power will be required? Can the millions of horse power of energy which is exhibited in lightning be seen on Mars? Is radio communication possible? Who is going to pay the cost of this gigantic power plant? What language are we going to speak? What are we going to talk about? Do the inhabitants of Mars know anything that we know, that is, can we find a topic of conversation? How are we going to determine whether or not they get our message? To the last question a school boy once replied, "Send the message collect and you will find out." These and many other difficult questions must be answered before we can establish satisfactory communication with the inhabitants of any planet.

ONE MOON OF MARS RISES IN THE WEST

Mars has two satellites (moons). These were discovered by Asaph Hall at the U. S. Naval Observatory in August, 1877, with the new telescope 26 inches in diameter—the largest in the world at that time. The moons of Mars are much closer to the planet than our moon is to the earth and move much more rapidly. The outer one, Deimos, is at an average distance of 14,600 miles from the planet's center and has a period of 30

hours and 18 minutes, while the inner one, Phobos, is at a distance of 5828 miles and has a period of 7 hours and 39 minutes, which is less than one-third of the planet's day.

Since Phobos goes around Mars faster than the planet rotates on its axis the inhabitants of Mars would see it rise in the west and set in the east two or three times a day. In fact, Phobos would rise every eleven hours. This is the only known example of a moon whose orbital velocity exceeds the velocity of rotation of its primary world, although the particles on the inner edge of Saturn's ring behave in a similar fashion. Since the period of revolution of Deimos is longer than the rotation period of Mars, this moon would rise in the east and set in the west. However, this difference is so small that 66 hours would elapse between its rising and setting, during which time it would exhibit all of its phases twice as it slowly drifted toward the west.

The moons of Mars are extremely small, Phobos being about 10 miles in diameter and Deimos about 5 miles. Neither moon shares the red color of the planet. Phobos is only about 3700 miles from the surface of Mars so that it could not be seen in any latitude higher than 69 degrees because of the curvature of the surface of the planet.

It is a well known fact that there is a reason for every name in astronomy and the names of the two moons of Mars are not exceptions to this general rule. What better names could be found for these two moons than Deimos and Phobos—meaning fear and panic—which, according to classical mythology, were the names of the horses attached to the chariot of Mars, the god of war.

THE FIRST PLANETOID WAS FOUND ON THE FIRST NIGHT OF THE NINETEENTH CENTURY

German mathematician, Kepler, interpreted the movements of the planets in mathematical terms. Of course there were only six planets known in his day—Mercury, Venus, Earth, Mars, Jupiter and Saturn—but each of his three celebrated laws applied to the motion of any of the six. Before he could formulate his Harmonic Law, which stated that the squares of the periods of any two planets were proportional to the cubes of their distances, he

determined the relative distances of the planets from the sun and noticed an apparent gap in the solar system between the orbits of Mars and Jupiter. He called attention to this gap and tried his best to account for it by some mathematical means but was unsuccessful.

When Bode's Law was published in 1772, giving a series of numbers which represent the relative distances of the different planets from the sun, provided we skip one number between Mars and Jupiter, scientific men began to discuss the possibility

$\frac{4}{4}$	$\frac{4}{3}$	$\frac{4}{6}$	$\frac{4}{12}$	$\frac{4}{24}$	$\frac{4}{48}$
<i>Mercury</i>	<i>Venus</i>	<i>Earth</i>	<i>Mars</i>	<i>(?)</i>	<i>Jupiter</i>

DISTANCES ACCORDING TO BODE'S LAW

of finding a new planet in the vacant space. In 1781 Sir William Herschel discovered the planet Uranus in the exact place predicted for it by Bode's Law and everyone became firmly convinced that, since all of the planets had been found at their proper places as fixed by Bode's Law, there surely must be some planet between Mars and Jupiter at a distance of about 2.8 units from the sun.

On September 21, 1800, an association of 24 astronomers was formed to find the missing planet. A careful search was immediately begun in spite of the opposition of a certain philosopher who explained that these astronomers were wasting their time on a useless task, because, for Biblical reasons, there could be no planet in this missing space. He pointed out that seven planets had already been discovered and that, since there were seven days in the week, seven colors in the rainbow, seven notes in the musical scale, seven openings in the head, etc., there certainly could not be more than seven planets.

After a search of about three months a small planet was discovered in the constellation Taurus on the first night of the nineteenth century, January 1, 1801. This planet was found by Piazzi of Sicily and was very naturally named after Ceres who

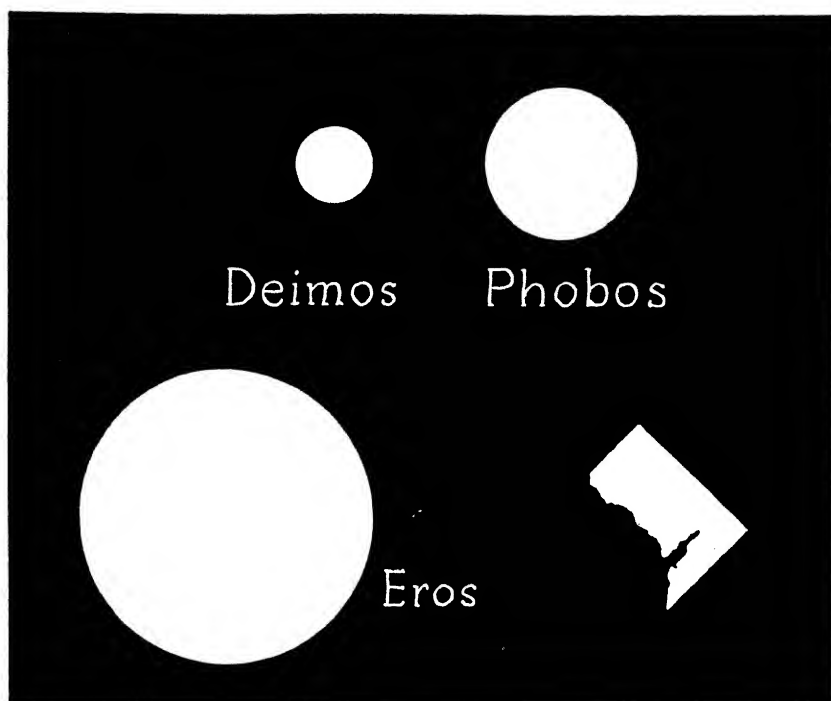
was the guardian divinity of the Island of Sicily. You will recall that Ceres was the goddess of agriculture and, with her daughter Proserpina, made her home in Sicily.

EROS DETERMINES THE SIZE OF THE SOLAR SYSTEM

Even after the discovery of Ceres in 1801, the astronomers still continued to explore the vacant space between Mars and Jupiter with the result that, in 1802, a second small planet was discovered which was named Pallas. In 1804 Juno was found and this was followed in 1807 by the discovery of Vesta, which is the only one of these planets ever visible to the naked eye. There were no more of these little planets discovered until 1845, although a large number have been found within the past century. All of these newly-discovered planets are moving around the sun just as the earth and Mars do. They obey all of Kepler's Laws of Motion and differ from the other planets only in size. For this reason they are known as "planetoids."

The little planetoid Eros actually comes so close to the sun that its average distance from that body is less than that of Mars and its period of revolution is only 643 days, while that of Mars is 687 days. Eros must come very close to the earth every time it makes a near approach to the sun and it has been carefully studied at the time of each of its seventeen visits since 1900. From these observations it is possible to calculate with great precision the dimensions of the solar system. Although this seems to be a rather indirect method of measuring our distance from the sun it is really one of the best methods we have.

In January 1931 Eros was only 16 million miles away, less than one-fifth of the distance from the earth to the sun and only seventy times as far away as the moon, and this is just about as close as this planetoid can ever get to us. From observations made at that time astronomers in both the northern and the southern hemispheres have announced that Eros is not a single globe, like the earth or the moon, but that it really consists of two planetoids revolving about one another. Each component seems to be about eight miles in diameter and their centers are



A comparison between the dimensions of the planetoid Eros, the two moons of Mars and the District of Columbia.

about seventeen miles apart. Here we have an enormous "dumb bell" in space whirling around an invisible axis with a period of about five hours and sixteen minutes. The two balls are held apart not by a bar of dense material, such as iron or wood, but by the invisible force of gravitation.

EROS HAS APPARENTLY LOST ITS FAVORED POSITION

On March 13, 1932, a new planetoid was discovered by E. Delporte at the Royal Observatory of Belgium which was destined to attract immediate attention. It was soon discovered that this planetoid may approach the earth even closer than Eros, which has held the record since 1898. This new object was carefully watched from several observatories for almost a month and enough observations were obtained to make a fairly safe predic-

tion about its orbit. The Delporte Planetoid, which was designated as 1932 EA₁, until the number 1221 was assigned to it, seems to be moving in a very flat ellipse around the sun with a period of about two and three-fourths years so that we should soon be able to determine its orbit completely.

We thought we were especially favored when, in January 1931, Eros came within sixteen million miles of the earth, but on March 23, 1932, the Delporte Planetoid was within ten million miles of us. It was then only about forty times as far away as the moon. This new planetoid has been named Amor, which is just another name for the little son of Mars and Venus who, soon after his birth, was appointed God of Love.

Unfortunately Amor was able to hold the distinction of being the nearest planetoid to the earth only about a month for on April 24, 1932, K. Reinmouth of Heidelberg, Germany, discovered another planetoid which comes even closer to us than Amor. This planetoid, which has been designated as 1932 HA, was very faint and it disappeared from view on May 15. From the many observations made upon it during the three weeks of visibility it seems that this planetoid has a period of about 1.8 years and that it not only crosses the orbit of the earth, but it even goes inside of the orbit of Venus. According to recent calculations the distance between this planetoid and Venus may sometimes be as small as 282,000 miles. If this is true we may make use of the Reinmouth planetoid for checking the weight of our twin sister, Venus.

No name has yet been proposed for the Reinmouth planetoid and probably it is just as well not to assign it a name until its orbit has been definitely determined. If it is finally called Cupid the earth will then be playing hide and seek with Eros, Amor and Cupid—three different names for the one god of love.

THOUSANDS OF PLANETOIDS FILL A GAP IN THE SOLAR SYSTEM

The host of little planets which move around the sun between the orbits of Mars and Jupiter look like stars, although they really behave like planets. For this reason Sir William Herschel called them "asteroids" which means "star-like." Since more

than twelve hundred and fifty asteroids have been discovered up to the present time, it is obviously inconvenient to assign names to all of them. The first four that were discovered were named from classical mythology. Ceres was the goddess of agriculture, Pallas was the goddess of wisdom, Juno was the wife of Jupiter and the queen of the gods, and Vesta was the goddess of the hearth, who watched over domestic life.

Ceres seems to be the largest of the planetoids, being about 485 miles in diameter. Pallas has a diameter of about 304 miles, Juno about 118 miles, and Vesta about 243 miles. Not a year has passed since 1847 without the discovery of from one to thirty planetoids and it is very probable that all of those fifty miles in diameter or larger have already been found. Eros, which was discovered in 1898 and is number 433 in the planetoid family, has a diameter of only fifteen miles.

One cannot contemplate the gigantic solar system with its nine large worlds and its almost twelve hundred "worldlets," all revolving around a central sun, without wondering about the origin of the planetoids, and why they happen to be just where they are. It was at one time thought that perhaps the planetoids resulted from the explosion of a single planet which once revolved around the sun between the orbits of Mars and Jupiter. It can be shown, however, from a study of their orbits that they could not have resulted from a single explosion.

They seem to be a part of a ring which completely surrounds the sun in much the same way that the beautiful ring of Saturn is related to that planet. The ring of planetoids is perhaps composed of a few large bodies which were naturally discovered first and a countless number of minute bodies which may be the result of the disintegration of larger bodies due to the attraction of the giant planet Jupiter. The planetoids are so very small that, if they were all combined into a single planet, it would require more than 3000 of these planets to weigh as much as the earth.

THE LARGEST WORLD WAS NAMED AFTER THE KING OF THE GODS

Beyond the ring of planetoids which completely encircles the sun lies the orbit of Jupiter, the giant planet of the skies. This

planet was named after Jupiter who, according to ancient mythology, ruled over both mortals and immortals. This supreme god of the universe, who held in his hand the destinies of both gods and men, seems to have been at first identified with Tius, the sun-god. However, as the wandering tribes separated they naturally changed the name of Tius as their languages developed. The Greeks called him Zeus, or to show greater reverence, Zeuspater, meaning "father Zeus." Closely related to this word is his Latin name Jupiter, as he was known among the Romans and some have suggested that his Hebrew name Jehovah had a similar derivation. The Latin word Deus, meaning "God," from which comes our word Deity, is obviously derived from Tius.

We learn from ancient legends that Jupiter overthrew his father Saturn, the god of time, and occupied the throne. In order to satisfy his two brothers, Pluto and Neptune, he made Pluto god over the lower regions under the earth and assigned the ocean to Neptune, who thus became the god of the sea. All the rest of the universe he retained as a part of his realm.

It would have been very natural for the ancients to name the largest planet in the sky after the most powerful god and they evidently did so, but we often wonder how they discovered that this particular world was larger than the others. We can understand how the rapid motion of Mercury, moving swiftly back and forth from one side of the sun to the other, suggested the name of the swift-moving messenger of the gods, and no optical aid is necessary to reveal the beauty of Venus or the ruddy color of Mars, which were named after the goddess of beauty and the god of war. At any rate the people of ancient times evidently determined in some way that the planet Jupiter, although sometimes not so bright as Venus, was the largest of the planets and they named it after the king of the gods.

The planet Jupiter is very easily recognized since, with the exception of Venus, it is the brightest planet in the sky. It generally appears much brighter than any fixed star, although Sirius, the most brilliant of all the stars, sometimes outshines it.

JUPITER IS ELEVEN TIMES AS LARGE AS THE EARTH

Jupiter has a mean diameter of 86,720 miles which is about eleven times the diameter of the earth, so that there are about 120 square miles on the surface of Jupiter for every square mile on the earth. The planet requires about twelve years for one trip around the sun. In other words, the children who were born on the planet Jupiter at the close of the World War are not yet two years old.

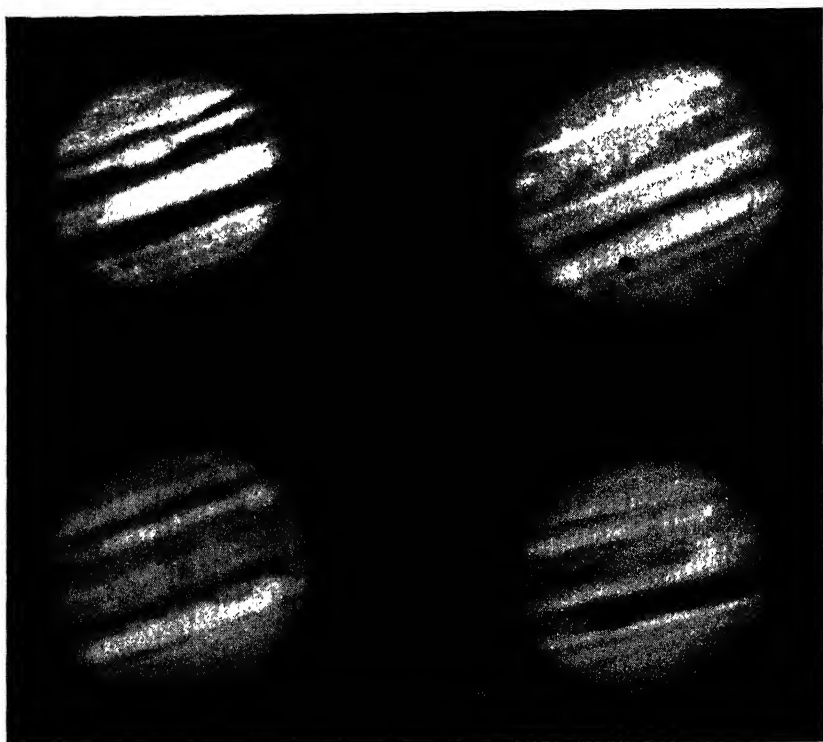
Surface gravity on Jupiter is about two and a half times that on the earth, so that those of us who are trying to reduce our weight should stay away from that planet. If we weigh 150 pounds on the earth we would weigh 375 pounds if we should move to Jupiter. A ton of coal, if transported to Jupiter, would weigh 5000 pounds.

Although Jupiter is a thousand times as large as the earth in volume and weighs 317 times as much as our world, its rotation period is only nine hours and fifty-five minutes. It is rather difficult for us to appreciate the amount of energy that is stored in this rotating planet. Our little earth is spinning on its axis so fast that a point on the equator is moving toward the east about 1,000 miles an hour. Since Jupiter is eleven times as large, the speed on its equator would be eleven times as great, if it rotated once in twenty-four hours like the earth does. But it spins more than twice as fast. Hence the speed of a person on its equator would be about twenty-five times as great as on the earth. In other words, this person would move toward the east with a velocity of more than 28,000 miles an hour.

It would probably take us some time to become accustomed to the ten-hour day on Jupiter. The labor unions, following their custom of dividing the day into three parts, one-third for work, one-third for play, and one-third for sleep, would demand a three-hour day on that planet. As a result of its rapid rotation the planet Jupiter is flattened at the poles to such an extent that its oblateness is noticeable through a large telescope. In fact its diameter at the equator is about 5,000 miles greater than its polar diameter. This is to be expected since Jupiter has the shortest day of all the planets.

JUPITER HIDES BEHIND ITS ATMOSPHERE

Jupiter has a very dense atmosphere. This is to be expected, for this planet is 317 times as heavy as the earth and its gravita-



Jupiter as photographed with 100-inch telescope, March 28, 1920, February 12, 1921, March 15, 1921, May 29, 1922. Note the moon Ganymede.—Mount Wilson Observatory.

tional attraction must be much larger than what we find on our own world. The clouds on Jupiter are always arranged in belts parallel to the planet's equator and are so heavy that we have probably never actually seen the surface of the planet. The disk of the planet is covered with an infinite variety of details, which change continually as it spins on its axis. These variable markings are in direct contrast with the fixed markings on Mars and are probably not on the surface of Jupiter, but in its atmosphere.

Different parts of the planet have different periods of rotation and the average of these periods is about nine hours and fifty-five

minutes. Markings sometimes drift by each other at the enormous rate of 350 miles an hour. Compare the speed of these air currents with the velocity of one of our own cyclones where the wind is usually moving between 70 and 100 miles an hour.

With his very crude instruments the French astronomer, Cassini, discovered a bright red spot on Jupiter in 1665, which later faded to pink and disappeared. A similar spot was found in July, 1878, by the American astronomer, Pritchett, which was 30,000 miles long by 7,000 miles wide. This spot was so large that the earth could almost have been thrown into it. In 1926 Dr. Slipher of the Lowell Observatory reported that the spot had faded to pink and that it had shrunk 10,000 miles in length and 700 miles in width. Recently a French astronomer announced that a new red spot was forming on the planet and that its dimensions are about the same as those of the one discovered in 1878. No satisfactory explanation of the behavior of these spots has yet been brought forward.

It was at one time supposed that the temperature of Jupiter must be very high and that, since the planet is much farther from the sun than the earth is, it must be hot on its own account. In other words, the planet must be a sort of semi-sun which, though not now hot enough to be self-luminous, has not yet cooled down to the temperature of the earth. However, recent investigations indicate a surface temperature of -400°F .

THE BELTS OF JUPITER CHANGE COLOR

The north and south equatorial belts of Jupiter vary in color, the maximum redness of the north equatorial belt occurring at the same time as the minimum redness in the south equatorial belt and vice versa. This change is periodic with a period of about twelve years. Since Jupiter makes one complete trip around the sun in 11.86 years, it is probable that the two periods are really the same and that the variation in color on the two sides of the equator is "annual"; that is, it occurs once a "year."

At first thought it might seem that the periodic change in the color of the north and south equatorial belts was the direct result of the seasons on the planet, but after a little thought it seems

unlikely that this can be true. We have seasons because the equator of the earth is inclined at a constant angle of $23\frac{1}{2}$ degrees to the plane of the orbit in which it is moving. In the case of Jupiter this angle is only about four degrees so that there can be no seasons on that world, at least in the sense in which we understand the word. Even if this angle were five or six times as large as it actually is there would still be very little variation in the seasons on Jupiter, for that giant world receives per unit area only $1/27$ th as much light and heat from the sun as the earth does.

Since there is no Spring, Summer, Autumn, or Winter on Jupiter the variation in the color of its equatorial belts cannot be attributed to the recurring seasons. But this variation seems to correspond exactly with the "year" on the planet, so that it must be in some way related to the sun. What is there about the sun, besides its heat and light, that might have some effect on Jupiter? Perhaps it is its gravitative attraction. This is worth investigating for, since Jupiter is larger than all the other eight worlds combined, the gravitative force operating between this planet and the sun must be enormous. Some researches along this line have recently been undertaken and it now seems probable that the many disturbances in the atmosphere of Jupiter may be the direct result of the gravitative attraction of the sun, but it must be admitted that this problem has by no means been solved.

GALILEO FOUND FOUR MOONS AROUND JUPITER

Jupiter has nine moons, four of which can be easily seen with an ordinary opera glass and were the first heavenly bodies ever discovered. Galileo made his first telescope in August, 1609, and began to study the moon and the different planets. This instrument was very crude and he continued to build better ones. On January 7, 1610, he turned his telescope on Jupiter and observed a small "star" very close to the planet on one side and two "stars" on the other side, the three "stars" being approximately in a straight line. The next night he found all of the three "stars" on one side of the planet. The next time he looked at Jupiter only two "stars" were visible and both of them were on the other

side. Several nights later he observed the two "stars" again and the third one became visible just before daylight when it came out from behind the planet. On January 13, he recognized four "stars" and he then became firmly convinced that these tiny points of light were not stars at all but were moons which belonged to Jupiter and were moving around the planet in a fixed plane just as Jupiter and the other planets were moving around the sun.

After Kepler learned about the four moons of Jupiter he wrote a letter to Galileo in which he stated, "I long for a telescope to anticipate you if possible in discovering two moons round Mars, six or eight round Saturn, and one each round Mercury and Venus." Here again Kepler made a "guess" almost as accurate as his statement of his Laws of Motion of the planets about the sun. As a matter of fact we have actually found two moons which belong to Mars, nine that belong to Saturn, but Mercury and Venus seem to be without satellites.

Many people were unwilling to believe that any of the seven planets that were known at that time could have moons revolving round them because seven was supposed to be a very sacred number and it would be simply impossible for any wandering bodies to exist in the sky except the seven which were already known. One writer of the Middle Ages expresses his views as follows: "The satellites are invisible to the naked eye, and therefore can have no influence on the earth, and therefore would be useless, and therefore do not exist."

JUPITER AND HIS NINE MOONS FORM A A MINIATURE SOLAR SYSTEM

Two of the four moons of Jupiter are about equal to our moon in diameter (1960 miles and 2320), and the other two are about the size of Mercury (3200 miles). They could be easily seen without optical aid were Jupiter not so brilliant. The other five moons are very small and have been found since 1892, the last one in 1914. Soon after the 36-inch telescope had been erected at the Lick Observatory in California, Dr. Barnard in 1892 discovered with this magnificent glass the fifth moon of

Jupiter. This moon is less than 80,000 miles from the surface of the planet and is very hard to observe. In fact it can be seen only by experienced observers with very powerful telescopes. The sixth and seventh moons of Jupiter were discovered by Perine with the Lick telescope in 1905. The eighth moon was found by Malotte at Greenwich in 1908 and Nicholson picked up the ninth satellite with the powerful Lick telescope in 1914.

Here we have a giant planet so large that the planets Mercury, Venus, Earth and Mars could all be placed inside of it, with nine heavenly bodies moving around it. Jupiter and its nine moons form a system analogous to our solar system except that the ninth moon revolves backward. It is thought that some of these moons may be planetoids which have been captured by this immense planet.

The four large moons of Jupiter change their positions very rapidly. One evening we may find all four of them on the same side of the planet and at another time we may find them all on the other side of the planet. Again some of them may be seen on one side and the others on the other side. We must remember that we have here a solar system in miniature. As the nine moons of Jupiter revolve around the planet they are held in place by the same force that causes the nine planets to revolve around the sun—gravitation.

As the satellites revolve about Jupiter they pass through the shadow of the planet at regular intervals and are eclipsed. The study of these eclipses led to the important discovery in 1675, by the Danish astronomer Roemer, that light has a finite velocity. In other words, a certain amount of time is required for light to travel from one celestial body to another.

EUROPA AND GANYMEDE NATURALLY BELONG TO JUPITER

The names of the four large moons of Jupiter are Europa, Ganymede, Io, and Callisto. It was very natural to give these moons names which were very closely associated with Jupiter, the king of the gods. Perhaps you may recall some of these legends from classical mythology.

One day Jupiter discovered the beautiful maiden Europa who lived in the northern part of Africa with her brother Cadmus, and immediately fell violently in love with her. The powerful king of the gods was able to change his form and shape at will, so he assumed the form of a white bull and approached Europa in the field. He whispered something in her ear and she immediately climbed upon his back. Jupiter then raced across the fields and over the mountains and through the valleys until he reached the southern border of the Mediterranean Sea. After swimming across the sea with Europa clinging to his back he came out in a new land which no one had ever seen before and which was called Europe after Europa. Europa became the mother of Minos, one of the principal judges in the infernal region, who questioned all newly arrived souls and assigned them to the proper degree of torment or bliss. Europa was also supposed to have been the grandmother of Deucalion—the Noah of the Flood according to Greek mythology. It is perfectly obvious then why one of these moons which spent eternity circling round and round the planet Jupiter should be named Europa.

You may recall that the gods and goddesses of ancient mythology lived on Mount Olympus, and that they were in the habit of meeting every evening at the banquet table. Hebe, the goddess of youth, served as the cup bearer of the gods. One day she stumbled and fell and created such a commotion that she was forced to resign. Jupiter then took the form of an eagle and flew out over land and sea looking for another cup bearer. He soon discovered Ganymede, the son of the king of Troy, who was said to be the most beautiful young man on the face of the earth. Jupiter quickly picked him up and flew swiftly with him to Mount Olympus and Ganymede since that time has been pouring nectar at the banquets of the gods. Thus we see why one of Jupiter's family of satellites is called Ganymede.

JUPITER'S FOUR MOONS BEAR THE NAMES OF HIS FRIENDS

Everyone who has read classical mythology is familiar with the fact that Jupiter, the king of the gods, numbered among his best

friends some of the most beautiful of mortal maidens. He was especially attracted by the beauty of Europa and in order that he might visit her alone, carried her off to a new land which he named Europe in her honor.

Io was another beautiful maiden with whom Jupiter, the king of the gods, carried on a clandestine flirtation on the earth. In order that he and Io might not be seen from Mount Olympus Jupiter usually spread a cloud over their meeting place. One day Jupiter and Io went out for a walk under the protection of a cloud and all went well until this stationary cloud aroused the attention of Jupiter's wife, Juno, who immediately came down onto the earth to see what was going on. Jupiter had just enough time to transfer Io into a heifer before Juno arrived on the scene.

Concealing her suspicions the Queen of the Gods took the heifer back to Mount Olympus with her and placed her in the custody of one of her servants, Argus, who had thousands of eyes and never closed more than half of them at one time. With the assistance of Mercury, Jupiter finally succeeded in putting Argus completely to sleep and liberating Io. Although Juno never completely recovered from the loss of Argus she consoled herself by gathering up the eyes of her faithful servant and scattering them over the tail of the peacock which she kept near her at all times. She also continued to torment the heifer by creating an enormous gadfly that followed Io from place to place until she finally plunged into what is now known as the Ionian Sea.

There is also a legend from classical mythology that connects Callisto with Jupiter. One day the jealous Juno discovered her husband in the company of the maiden Callisto and in order that Jupiter might no longer be able to recognize his companion, she transformed the beautiful maiden and her son into two ugly bears. Jupiter saw through their disguise and placed them in the sky where they could be near him at all times.

I think I have now told enough of these stories to explain why the four large moons of Jupiter should be named Europa, Io, Ganymede, and Callisto.

THE ANCIENTS NAMED THE MOST REMOTE PLANET AFTER GOD OF TIME

Saturn is the most interesting planet in the sky and is the most remote planet known to the ancients, who were unaware of the fact that there were other members of the solar system beyond the reach of the unaided eye. It is unique among the heavenly bodies, being surrounded by a system of rings which, so far as we can determine, has no counterpart elsewhere in the universe. In brilliance Saturn is inferior to Venus and Jupiter but it outshines all the fixed stars except Sirius. The brightness of Saturn varies because of the phases of the rings. Even Jupiter with all of its satellites cannot compete in beauty with the marvelous system of Saturn. This planet is one of the three most interesting objects in the heavens. The other two are the nebula in the constellation Orion and the great star cluster in Hercules.

It was very natural to name this planet which moves so slowly and majestically at the outskirts of the solar system after Saturn, the god of Time. Saturn was the son of Uranus (the sky) and Gaea (the earth). He was at one time ruler of the universe, having dethroned his father, Uranus, with the assistance of his mother. Of course Uranus became very angry when he was deprived of his throne and prophesied that some day Saturn also would be dethroned by his children.

Saturn paid no attention to this prophecy until his first child was born. He then remembered the calamity that was in store for him and decided to play safe by swallowing his son. One after another the children of Saturn disappeared down his throat until the sixth child, Jupiter, was born. In order that she might save this child from the fate which had befallen the others, his mother substituted a stone wrapped in children's clothes which Saturn swallowed thinking that he was thus putting Jupiter out of the way. After Jupiter became a grown man he dethroned his father according to the prophecy and became the well known and powerful king of the gods. Of course the story of Saturn swallowing his children is merely an allegory and is symbolic of the fact that time creates only to destroy.

The Greeks called the god of time, Chronos, and from this

word is derived many English words which involve the idea of time, such as chronology, chronometer and chronograph.

THE UNLUCKY WORLD, SATURN, IS NINE TIMES AS LARGE AS THE EARTH

People of olden times had no telescopes and consequently they were unaware of the existence of the planets Uranus, Neptune, and Pluto, which can be seen only with optical aid. They detected the motion of Saturn among the stars and were convinced that this planet, which was moving more slowly than any of the others, must be on the outskirts of their universe and almost as far away as the fixed stars. They watched the planet move slowly from star to star and were surprised to find that, although Mercury would flit back and forth from one side of the sun to the other and Venus would move rather quickly from morning star to evening star and then back again, Saturn would require two weeks to move a distance equal to the apparent diameter of the full moon. Its motion was slow, but sure, and consequently this planet was named after the god of Time.

In the early days of astronomy every one was interested in the proposed effect of the stars and planets on human affairs, and Saturn was always supposed to have an evil influence. Consequently, it was generally considered bad luck to do anything on Saturday, the day which was ruled over by this planet. This probably explains our Saturday holidays and half-holidays.

The diameter of the planet Saturn is about 71,500 miles which is about nine times the diameter of the earth. Its surface is, therefore, about 81 times, and its volume about 734 times, that of the earth. The globe of Saturn is much smaller than Jupiter. However, its claim to beauty is not due to the size of its globe but to the marvelous system of rings by which it is surrounded—a system which is wonderful from every point of view.

Because of a well known law of nature the rotation of a planet causes it to be flattened at the poles, and in general we find that the more rapidly a planet rotates the flatter is the planet. Saturn rotates much more rapidly than the earth and consequently is much flatter than our planet, its oblateness being very conspic-

uous through a large telescope. The diameter through the equator is about 75,000 miles and the diameter through the poles is less than 70,000 miles. In other words, the diameter given above, 71,500 miles, is what may be called an "average" diameter.

SATURN WOULD FLOAT IN WATER

Everyone knows that the earth is 93 million miles from the sun but when we try to visualize this enormous distance we simply cannot do it. Our minds are not built that way. We talk about millions and billions just as if they were dozens and hundreds but if we should attempt to spend a fortune of \$93,000,000 at the rate of a dollar a minute we would have to begin at birth and spend sixty dollars every hour, night and day, until we were one hundred and seventy-seven years old in order to get rid of it.

If we find it difficult to appreciate the distance which separates us from our source of light and heat, then how about the inhabitants of Saturn who are ten times as far from the sun as we are? To these people the sun would appear very much smaller and would give them only about one-one hundredth as much heat per square yard as it so lavishly pours upon our earth. Saturn is moving around the sun at the rate of about six miles per second, or 16,000 miles per hour, but it has so far to go that a year on Saturn is as long as thirty of our years.

Another interesting thing about Saturn is the fact that, although the planet is 95 times as heavy as the earth, its density is only about one-eighth of the density of the earth which means that it is only two-thirds as dense as water. In other words, the planet Saturn would float in water. It is the least dense of all the planets.

The rotation period of Saturn is rather difficult to determine because it is only on rare occasions that well defined spots appear on its surface. We find that different parts of the planet rotate with different periods and that the nearer the spot is to the equator the more rapid is the rotation. The average period of rotation seems to be about 10 hours and 15 minutes. However, it is barely possible that what our telescopes reveal upon Saturn

is not a solid surface but merely a vast envelope of clouds surrounding the planet. The spots are not very well defined and are probably not on the planet at all but in its atmosphere. Like the planet Jupiter, Saturn also has a number of belts which are parallel to the equator.

SATURN ROTATES IN ABOUT TEN HOURS

It is possible to calculate the mass of any of our neighboring worlds with great accuracy—especially if they have one or more satellites—by mathematical formulas and computations that are far beyond the average person. We also have instruments that enable us to compute their diameters as soon as their distances from the earth are known. However, when we attempt to determine the rotation period of a planet it is absolutely necessary for us to find on its surface some permanent mark, or other feature, that will rotate with the planet. For example, the little red planet Mars exhibits many well defined surface markings and we can determine its rotation period with great accuracy merely by watching these markings as they come into view on one limb of the planet and gradually pass across its disk only to disappear around the opposite edge.

Perhaps the inhabitants of Mars have already determined the length of our day by watching Berlin, Paris, London, New York City, Saint Louis, Denver and San Francisco follow each other in solemn procession across the face of the earth as our world spins silently around its axis. Of course these people could not see us as we go about our everyday affairs, but if they have astronomical instruments in any way comparable with ours they could certainly see the cities and other landmarks that we have created, except when these objects are hidden by intervening clouds in our atmosphere.

Saturn, like Jupiter, has always been very reluctant to furnish us any exact information about its rotation period. Only on very rare occasions have any spots appeared on this planet and these have been intensely brilliant white and not red, as in the case of some of the spots on Jupiter.

After studying a white spot that appeared in the equatorial

zone of Saturn in 1876, Hall announced that the rotation period of the planet was ten hours and 14.4 minutes. Some spots appeared in 1903 about thirty-six degrees north of the equator and Barnard announced that the rotation period of that part of the planet was ten hours and thirty-eight minutes. Early in August 1933 a brilliant white spot appeared in the equatorial zone of Saturn so that it was possible to again determine the equatorial rotation period. After making a series of observations of this spot Dr. Latimer J. Wilson found an equatorial rotation period of ten hours and fifteen minutes.

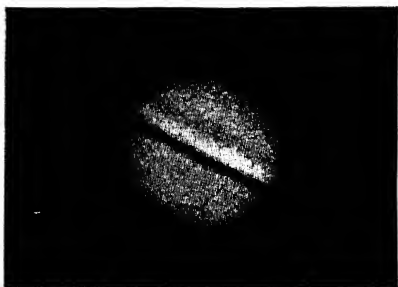
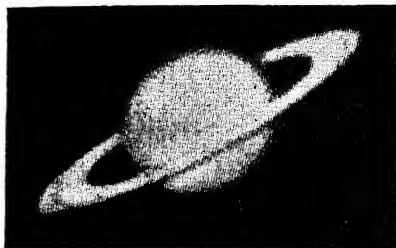
SATURN'S RING SYSTEM IS UNIQUE

Although the planet Saturn is not as bright as Venus or Jupiter it is one of the most interesting objects in the sky. Venus amuses us by going through all of the phases of the moon as it moves back and forth from one side of the sun to the other and Jupiter holds our attention by presenting to us a family of moons which entertain us by their rapid motion around the planet, each in turn disappearing for a short time as it passes through the shadow of that giant world. But Saturn causes us to hold our breath in amazement as we study the system of three concentric rings which completely surround the planet. No other world with which we are familiar can boast of such an appendage.

The rings of Saturn were discovered by Galileo in 1610 immediately after he began building his little telescopes. He soon lost them and they remained lost for nearly fifty years until the Dutch astronomer, Huygens, re-discovered them in 1655. Twenty years later the French astronomer, Cassini, noticed that what had been called "the ring" was really two concentric rings with an open space between them and in 1850 Professor Bond of the Harvard Observatory discovered the dark ring next to the planet.

The rings disappear from time to time and then reappear again, since the plane of the rings is inclined to the plane in which the planet is moving. Saturn makes one complete circuit around the sun every thirty years and twice during this period the rings are directly in line with the earth. We then see them

edgewise and they disappear completely from view except with the very largest telescopes, because they are so very thin. Of course about seven years after the rings have disappeared they will again present their largest area to us.



Saturn's rings present an ever changing appearance to us, disappearing every fifteen years.

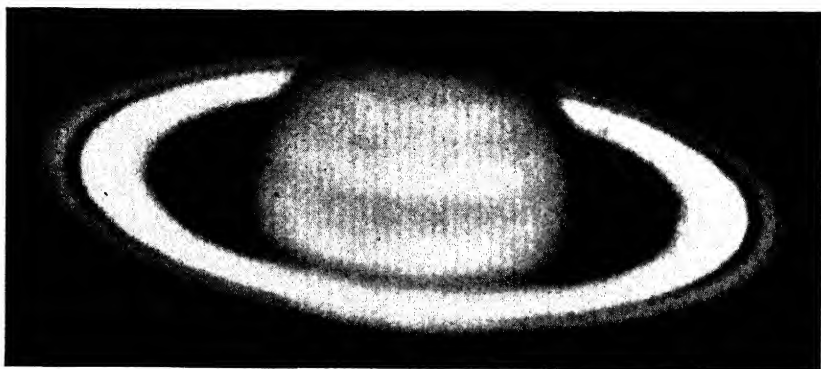
The diameter of the outer ring is 173,000 miles and its width is about 10,000 miles. The second ring has a width of 16,000 miles and the dark ring is 11,000 miles wide, leaving a clear space of 7,000 miles between the dark ring and the planet. The rings are very thin, being less than fifty miles in thickness. On account of the curvature of the surface of Saturn the rings could not be seen in latitudes higher than sixty-three degrees.

MILLIONS OF SEPARATE PARTICLES FORM SATURN'S RINGS

Saturn with its system of rings and moons is one of the most interesting objects in the sky and a study of this planet will bring out of a man all the wonder, reverence and joy in the

wonderful creations of his maker. The planet is visible to the naked eye but everyone should take advantage of every opportunity of looking at Saturn through a large telescope, which will furnish a view of this planet that will long be remembered.

Perhaps you are already wondering about the composition of the rings of Saturn. They are spinning around the planet very rapidly, so that we can be sure that they are not solid, because if they were they would be torn to pieces by the rapid rotation.



Photograph of Saturn.—Yerkes Observatory.

It was less than a hundred years ago that this mystery was solved. Everyone believed that the rings were either solid or liquid, but it is now universally agreed that they are not continuous sheets, either solid or liquid, but a swarm of separate particles—little “moonlets”—each pursuing its own independent orbit around the planet and forced by the law of gravitation to move in a flat plane like the brim of a straw hat.

This is one of the most interesting things about Saturn. Here we have a planet with millions of little moons circulating around it, each moon moving on its own orbit under the attraction of the same force that holds the earth in its orbit around the sun. We are indebted to the British physicist, James Clerk Maxwell, and the American astronomer, James Edward Keeler, for the solution of the mystery of the composition of Saturn's rings.

By means of that wonderful instrument which we call the spectroscope we can determine the velocity of any point of the ring, and we find that every point of the ring is moving with just exactly the same velocity it would have if it were a separate satellite. Particles on the inner edge of the ring revolve about

the planet in about five hours while those on the outer edge require about fourteen hours for one revolution. The "moonlets" on the inner edge, like the inner moon of Mars, revolve faster than the planet rotates. Just as soon as it was discovered that the outer edge of the ring was moving more slowly than the inner edge it was immediately evident that the ring could not be solid.

SATURN HAS NINE MOONS

Saturn, like Jupiter, has a family of nine moons; that is, nine large moons in addition to the millions of "moonlets" which form the ring. The largest of Saturn's moons, Titan, was discovered by Huygens in 1655. Between 1671 and 1884 Cassini discovered Iapetus, Rhea, Tethys, and Dione. The great English astronomer, William Herschel, picked up Mimas and Enceladus in 1789, Bond of Harvard Observatory found Hyperion in 1848 and W. H. Pickering in 1899 discovered Phoebe. In 1905 Pickering announced the discovery of a tenth moon of Saturn which he called Themis, but this discovery has not yet been confirmed. Some authorities contend that this so-called moon was merely a planetoid which happened to be in the field of view at the time.

As in the case of the four large moons of Jupiter, the nine moons of Saturn are all named after mythological characters which were more or less closely associated with the god Saturn. Uranus, the father of Saturn, had six gigantic sons, the Titans, and six gigantic daughters, the Titanides. Hyperion and Iapetus were two of the Titans and Phoebe and Rhea were two of the Titanides. Tethys was another sister of Saturn and the mother of the Oceanids. Mimas and Enceladus were terrible monsters, the latter having been created by Saturn's mother in order to avenge his death. One moon was called Titan and another was named after Dione, the goddess of moisture.

Titan, as its name suggests, is the largest moon of Saturn. This moon is about 2600 miles in diameter, so that it is somewhat larger than the moon that belongs to the earth. Rhea and Iapetus are about the same size, being much smaller than Titan and only about one-half the size of our moon. Tethys and Dione are about 800 miles in diameter. Enceladus has a diameter of 500 miles and Mimas of 400 miles. The diameter of Hyperion

is about 300 miles, while Phoebe, the least of all, has a diameter of about 150 miles.

All of Saturn's nine moons revolve around the planet in the direction in which the planet is moving except Phoebe, which moves backward in its orbit. However, the mathematicians tell us that the plane of this orbit is gradually changing until, after several million more years, this moon will move in the proper direction around Saturn, and everything will then be in perfect harmony.

SIR WILLIAM HERSCHEL ACCIDENTALLY DISCOVERED A NEW WORLD

Mercury, Venus, Mars, Jupiter and Saturn have been known from remote antiquity so that no one can claim the discovery of any one of them. They were observed by men of all nations and in all ages and no additions were made to this family of worlds until long after the invention of the telescope when a planet was found accidentally on March 13, 1781 by Sir William Herschel while trying out a new seven-inch telescope that he had just constructed. This new and interesting object showed a disk in his telescope so that he knew that it was not a star. He very naturally thought he had discovered a new comet. In fact it was not until about one year later that he became aware of the fact that he had added one more member to the solar system. Herschel called this new object "George's Star" in honor of his king, but the name Uranus which was suggested by Bode finally prevailed.

We learn from classical mythology that soon after the beginning of creation Chaos (confusion) and Nyx (night) were overthrown by Uranus (the sky) and his wife Gaea (the earth), who seems to have been the first of that glorious succession of gods who ruled from the summit of Mount Olympus. Uranus was the god of the sky and was the father of six gigantic sons and six gigantic daughters, who were hurled into the lower regions by their father just as fast as they were born because he feared their strength. Uranus was also the father of three other sons, Thunder, Lightning and Sheet-Lightning, who were also thrown into the lower regions. Only one of these children ever

managed to escape from this cavern and he (Saturn) finally dethroned his father and reigned in his place.

The planet Uranus is about 32,000 miles in diameter and is barely visible to a good eye, provided we know where to look for it. Since its diameter is about four times the diameter of the earth, its surface area must be about sixteen times the area of the earth. Its distance from the sun is about nineteen times the distance of the earth from the sun and this planet moves around the sun so slowly that eighty-four years are required for one complete trip. In other words, the earth makes eighty-four trips around the sun while Uranus is making a single circuit.

URANUS HAS A YEAR OF SIXTY-EIGHT THOUSAND DAYS

Uranus is rotating on its axis much more rapidly than the earth, its rotation period being about ten hours and forty-five minutes. Its rate of rotation is so fast and its rate of revolution about the sun is so slow that the planet actually turns on its axis 68,000 times while it is making one trip around the sun. That is, an inhabitant of Uranus would give you the startling information that his year contains 68,000 days instead of 365 days, the number to which we are accustomed.

Immediately after the discovery of Uranus the question naturally arose as to whether this new world had any moons revolving about it. Jupiter had its retinue of satellites and Saturn had its rings and moons so that Uranus probably had some small attendants if only the telescope were powerful enough to reveal them.

Uranus has four moons, two of which were discovered by Sir William Herschel six years after he found the planet. The two smaller ones were found by Lassell in 1851. These satellites are very faint and are among the most difficult heavenly bodies to observe. The plane of their orbit is almost perpendicular to the ecliptic and all four of the moons are moving backward in that orbit. We are told, however, by the mathematicians that the plane of this orbit is gradually rising, so that it will soon pass the ninety degrees point and then the motion of these moons will be forward instead of backward.

Perhaps you are already wondering about the names of the moons of Uranus. These companions of Uranus were named Ariel, Umbriel, Titania and Oberon. Titania, as the name implies, is the largest, having a diameter of about 1,000 miles. You will recall that the names of all of the planets and the names of all of the moons of all the planets (except Uranus) were derived from classical mythology. However, we have here a complete change of mythology since these names are derived from English literature. Sir William Herschel and his fellow countrymen probably thought that, since England had produced her Shakespeare and her Pope, it was not necessary to go back to the classical literature of Homer and Virgil. Those of you who are familiar with Shakespeare's *Tempest* and *Mid-Summer Night's Dream* will immediately recognize Ariel, Titania and Oberon. If you are also acquainted with Pope's *Rape of the Lock* you will recognize Umbriel as an old acquaintance.

URANUS ONCE REFUSED TO MOVE IN ITS PREDICTED ORBIT

The story of the discovery of Neptune is one of the most interesting chapters in the entire history of astronomy. This planet was actually figured into existence by a mathematician with his pencil and paper long before it was seen through a telescope. The fact that this mathematician, after an enormous amount of calculation, was able to say to a practical astronomer, "point your telescope in a certain direction at a certain time and you will see a new world," is one of the greatest triumphs in the history of that queen of sciences, mathematics.

Soon after Sir William Herschel had discovered Uranus the mathematicians determined where the planet should be at any given time. For several years Uranus seemed to follow this path, but early in the nineteenth century it was noticed that the planet was not in the exact position which had been predicted for it. A new orbit was then worked out, but Uranus soon got off of the track again so that astronomers were convinced that something was wrong. Either there was an error in mathematical calculations or the law of gravitation did not hold at that great distance from the sun or there was some hitherto undiscovered

heavenly body that was trying to attract attention by pulling Uranus off the track.

The young mathematicians, Adams in England and Leverrier in France, became convinced that there was another planet somewhere in the solar system that man had never seen and that it was because of the attraction of this planet that Uranus was unable to stay in its orbit. Each of these men independently determined to find this planet and each man was rewarded by its discovery.

No telescope was required for this work. The mathematician merely assumed the existence of an unknown planet at a certain point in the sky and that it had a certain mass. He would then go through a long mathematical calculation and determine what effect the existence of this planet at that place would have on Uranus. If this correction did not bring Uranus back on the track, he would then begin again with a different mass and a different position of the planet. You can imagine the amount of labor involved in this mathematical process. In fact, Sir George Airy, Astronomer Royal of England, stated about 1840 that the problem could not be solved, which probably accounts for his lack of interest several years later.

NEPTUNE WAS ACTUALLY FIGURED INTO EXISTENCE BY MATHEMATICS

The year 1845 found two mathematicians working quietly with pencil and paper, each determined to figure a new world into existence. Neither man knew that the other man was working on the problem. In October, 1845, Adams in England wrote a letter to the Astronomer Royal in which he announced the approximate position of the planet, but for some reason this communication was laid aside and the search for the new planet postponed. In June, 1846, Leverrier in France announced to the world his theoretical position of the planet, which was very close to the place where Adams had said the planet would be found. This communication was also sent to the Astronomer Royal and still no search was made.

In an address before an association of scientists on September

10, 1846, Sir John Herschel uttered these prophetic words—"The past year has given to us the new planet, Astraea; it has done more—it has given us the probable prospect of another. We see it as Columbus saw America from the shores of Spain. Its movements have been felt trembling along the far reaching line of our analysis with a certainty hardly inferior to ocular demonstration."

After carefully checking over his results and convincing himself that they were correct Leverrier wrote a letter to Dr. Galle, head of the observatory at Berlin, and told him exactly where he believed the planet was situated at that time. Galle got this letter on the twenty-third of September, 1846, and that same night he pointed his telescope as directed and within half an hour after he had begun the search he found the new planet less than one degree from the place where Leverrier said it would be found.

Had the Astronomer Royal of England put sufficient faith in the letter of the brilliant young English mathematician and pointed his telescope at the place indicated he would have discovered this planet within one degree of the point where Adams said it was and about eleven months earlier than the date on which it was found by Galle. This is the story of the discovery of the planet Neptune which, as we have just stated, was actually figured into existence by mathematicians using nothing but pencil and paper. What a triumph for the law of gravitation! The new planet was named after Neptune, the brother of Jupiter, who was the god of the sea.

NEPTUNE SEEMS TO HAVE ONLY ONE COMPANION

The planet Neptune which was discovered mathematically with pencil and paper before it was ever seen through a telescope is invisible to the naked eye. It has a diameter of about 31,000 miles and is moving slowly around the sun at the rate of about three and one-third miles a second. Its distance from the sun is about thirty times the distance of the earth from the sun, so that a long time is required for this planet to make a complete

circuit around that body. In fact, the earth makes 165 trips around the sun while Neptune is making one trip, so that a year on Neptune is as long as 165 years on the earth. The planet has not made one complete circuit about the sun since it was discovered in 1846, so that the children who were born on the planet that year, if there were any, are not one year old yet.

We have seen that all of the other planets are rotating on their axes, and the rotation periods of most of them are known with accuracy. However, on account of the great distance from the earth to Neptune it is very difficult to accurately determine the rotation period of that planet. Recent researches indicate that its period of rotation is about sixteen hours. The great distance from the earth to Neptune can best be illustrated by the statement that, when we look at the planet the light by which we see it leaves the sun more than eight hours before it reaches us. In other words, more than eight hours are required for light, traveling at the tremendous speed of 186,000 miles a second, to make the trip from the sun to Neptune and then back to us.

Neptune is so far away that the sun, as seen from Neptune, would be about the size of Venus when looked at from the earth. The brightness of the sun, as seen from Neptune, would be about the same as a 1200 candle power light at a distance of twelve feet.

Neptune has one moon; that is, we have not yet been able to discover any more. This moon, Triton, was found about a month after the discovery of Neptune. It is very probable, however, that the planet has several other moons which are small and will remain invisible until we learn to construct telescopes that are much more powerful than those we have built up to the present time.

THE LATEST ADDITION TO SUN'S FAMILY WAS FOUND IN 1930

Soon after the discovery of Neptune in 1846 scientists began to wonder about the existence of a ninth planet beyond Neptune's orbit and the French astronomer, Flammarion, went so far as to suggest that the irregularity in the motions of certain comets was probably due to the attraction of this undiscovered

planet. A number of astronomers attempted to locate this planet, just as Adams and Leverrier located Neptune, and came to the conclusion that there were probably several of these worlds awaiting discovery. The sun's domain does not end at Neptune. A planet might be 400 times as far from the sun as Neptune and still belong to the sun. A ray of light, which requires only four hours for a trip from the sun to Neptune, will not reach any other sun for more than four years. The solar system is an island in space and there is plenty of room for hundreds of planets to circle the sun beyond Neptune's orbit and still not be close enough to any other sun to be attracted to it.

A few skeptics refused to consider the possibility of a ninth planet and were convinced that much valuable time was being wasted by those who were searching for it. "Does not Bode's Law break down with Neptune?" they said. "Then how can there be a planet beyond?" As a matter of fact since there is no mathematical foundation for Bode's Law the breaking down of this law at Neptune means nothing. If it meant anything it would mean that there was no Neptune.

Many able mathematicians have devoted much time and attention to the problem of finding the planet predicted by Flammarion among whom was Percival Lowell, who founded and endowed the Lowell Observatory for the purpose of studying Mars and searching for the new planet.

After years of research the image of the long sought planet was found in the direction of the constellation Gemini by C. W. Tombaugh of the Lowell Observatory, on a plate taken January 21, 1930. What a pity that Percival Lowell could not have lived to see this planet discovered almost exactly in that part of the sky predicted by him. What if it does turn out to be much closer to the sun than he thought? Surely to be able to point out the constellation in which it would be found was an achievement of the first rank.

THE NEWEST WORLD WILL PROBABLY CARRY THE NAME PLUTO

Many names have been suggested for the new planet discovered at Flagstaff in 1930, the most popular being Lowell or

Percival, in honor of the founder of the Observatory. However, it is very probable that since all other planets have classical names this new world will carry some name from classical mythology. Scientists seem to be agreed that since Jupiter and



Pluto, as photographed at the Lowell Observatory on March 4, 1930, by C. O. Lampland.

Neptune, two of the sons of Saturn, have been honored with positions in the sky, this new planet should be named Pluto, after the third son, who was the ruler of the underworld.

Many months must elapse before the astronomers will be able to give us accurate figures with reference to the planet Pluto—its distance from the sun, its diameter, its period of revolution, its rotation period, its satellites, etc.—so that the tentative figures which follow will surely be revised in the light of later computation. From the meager information already ob-

tained about the planet astronomers believe that the distance from the sun to Pluto is about 40 astronomical units (Neptune's distance is 30) and that it requires about 250 years to complete one circuit about the sun. The planet is probably much smaller than the earth and its mass is unknown.

Pluto resembles Mercury, Venus, Mars and the earth much more than it does the giant planets Jupiter, Saturn, Uranus and Neptune, which are much closer to it. Its orbit is even more eccentric (flatter) than that of Mercury. This fact, together with its high inclination to the ecliptic (seventeen degrees), may mean that Pluto is related to the planetoids, of which we have already found more than twelve hundred. But even so—it is moving around the sun so that it is a planet that belongs to our solar system.

What lies beyond Pluto? Are there other members of the sun's family of worlds quietly circling the sun out there in the depths of space and awaiting discovery? What if Pluto is 3,700,000,000 miles from the sun? Does not the sun's realm extend more than 300 times this distance, so that its gravitative power would control the movements of any heavenly body within a radius of a million million miles? Of course these questions cannot be answered at the present time and one would be very unwise to attempt to predict what the improved telescopes, and other "scopes" not yet dreamed of, will reveal inside the enormous domain of the sun.

CHAPTER IV

Our Lunar Companion

THE MOON WAS PROBABLY THROWN OFF FROM THE EARTH

IS THERE anyone so busy or so interested in life's daily routine that he is not fascinated by the moon as it floats majestically in the summer sky, sometimes hiding its face behind an intervening cloud and again flooding the landscape with its silvery light? To those who are acquainted with the fact that there are twenty-six moons in the sun's family it may seem somewhat presumptuous to refer to this heavenly body as "the" moon. However, this is the only one of the twenty-six moons that belongs to the earth and for that reason we are perhaps justified in our use of the definite article.

The moon has been our companion for ages and it is very probable that it actually shared in the origin of the earth, so that it was throwing its soft light upon the terrestrial landscape long before there were any human beings to enjoy it. Some scientists are of the opinion that the earth at one time rotated much more rapidly than it does now and that the material which now forms the moon was actually thrown off of the earth by the centrifugal force generated by the rapid rotation. They call our attention to the fact that the density of the moon is almost exactly that of the rocks which underlie the surface crust of the earth and they even name the hemisphere and the zone from which the moon broke off. Others tell us that the earth and moon were produced together at the time of some great catastrophe. Be this as it may, the moon serves as our constant companion on our endless journey through the depths of space. To the observer on Venus or Mars the earth and the moon would appear to form a beautiful double planet. Although

five of the other worlds have moons no other satellite is so large as our moon in comparison with its primary world.

Not only did the moon share in the origin of the earth but it also prefigures our decay and death. The moon, being much smaller than the earth, dried up much more rapidly so that now both air and water are entirely absent from its surface. Our companion is now in a condition such as will probably be found on our own planet after a few million years, when the earth shall have dried up and all human life shall have disappeared.

THE MOON MAY BE THE EARTH'S DAUGHTER

There are many reasons for believing that the moon was once a part of the earth and that it was actually thrown off into space by the rapid rotation of our planet. There seems to be no question but that when the earth was very young it was in a molten state and was revolving on its axis much more rapidly than it revolves today. While in this stage the attraction of the sun must have raised great tides on opposite sides of the earth's surface which swept around the equatorial belt from east to west as the planet rotated in the opposite direction. After a while—astronomically speaking—the motion of the tidal waves increased to such an extent that a part of the molten earth broke away and was thrown a short distance into space. Thus was born the Moon, the daughter of the Earth by the Sun.

If we assume that the moon, which is composed of materials exactly like those to be found in the crust of the earth, was thrown out into space by the force of the earth's rotation, we can show mathematically that the forces of nature would require it to gradually move off from the earth until it reached its present position. The gravitational attraction between the earth and the moon would raise tides on the surface of each which would in turn retard the rotational speed not only of the moon but also of its mother, the earth. Since the earth is about eighty times as heavy as the moon, the effect on the rotation period of the moon would be much greater than on that of the earth. As a matter of fact, tidal friction has already slowed up the

moon's rotation until it now rotates on its axis exactly once as it makes its monthly circuit about the earth. In other words, it keeps the same face constantly toward the earth and no mortal has ever seen the back side of the moon.

The young planets, Jupiter and Saturn, rotate in about ten hours so that they spin on their axes about two and a half times as fast as the earth does. Perhaps when the earth was no older than these planets it also rotated very rapidly but, having lost a part of its molten surface equivalent to one-eightieth of its mass, it has gradually slowed down to its present speed.

ANCIENTS CONSIDERED THE MOON AS TWIN SISTER OF SUN

The sun and the moon, always closely associated, were worshipped as gods by primitive peoples and were intimately connected with the life of mankind. It was the duty of Apollo to drive the sun chariot on its daily trip across the sky after the pearly gates of dawn had been opened wide by the rose-tipped fingers of the goddess Aurora. Only in this way did it seem possible for the inhabitants of the earth to enjoy light during the day time. These same peoples also worshipped Diana, the goddess of the moon, whose duty it was to drive the moon car across the sky so as to give them some light while Apollo was resting from his labors. Ancient literature contains many beautiful legends about the twins, Apollo and Diana, the son and daughter of Jupiter, the king of the gods.

Among the Indian tribes of North and South America are to be found many legends about the sun and the moon. The sun-god was regarded by some tribes as a creator who ruled supreme and in his honor were erected temples that were adorned in all magnificence. Everything in their small world which they considered beautiful and useful was dedicated to the all-powerful sun-god.

Some tribes believed that the sun was the home of the chief deity. On the moon dwelled his wife and the children lived on the stars and the planets. Since these heavenly bodies moved about in the sky, the gods and goddesses could easily watch over

all the tribes. It was sometimes believed that the moon and stars came to the earth in the day time to mingle with the people and at night the sun descended. Thus did they explain the rising and setting of the sun and the moon.

To all tribes, however, there was a Great Spirit and a varying degree of worship of the sun and the moon. We learn that the Great Spirit created the moon first and, being disappointed in the amount of light which was obtained from that luminary, he then created the sun. The sun and moon seem to have been worshipped as living beings, the sun generally being considered as a male and the moon as a female. However, some peoples who lived far from the equator where the nights were cold and severe and the days were mild and pleasant considered the moon as a man and the sun as a woman.

THE MOON FAILED TO DESTROY HER CHILDREN

Early peoples had many interesting legends about the sun and moon. We are told that among the inhabitants of the Malay Peninsula there is a legend to the effect that the sun and the moon are both women and that the stars are the moon's children. Each woman at one time had a large family but the sun, growing tired of her many responsibilities, suggested to the moon that they both destroy their children. The moon at first agreed but, after the sun had killed hers, she changed her mind and failed to carry out her part of the agreement. Of course this is merely an allegory. The sun devours her children at dawn and the moon brings hers out only after the sun has disappeared. When the sun re-appears and discovers that the moon has failed to put an end to her children she immediately becomes very angry and pursues the moon across the sky.

The ancient Hebrews regulated their calendar by the moon. The month began when they first saw the thin crescent moon in the western sky at sunset and ended when the moon got into the same position again; that is, their month ran from new moon to new moon. In fact the word "month" is evidently derived from the word "moon." Since the Hebrews were watching the western sky at sunset, looking for the new moon which was to mark the beginning of the next month, it was natural

for them to begin the day at sunset, so that the day and the month would begin at the same time. We are not surprised, therefore, when we read in the Book of Genesis, "and the evening and the morning were the first day."

The Druids worshipped the moon. They believed that when a person died his spirit went to the moon, which was the place of abode after death. The moon was to them the visible sign and pledge of immortality and so firmly did they believe that they would begin to live in a state of perpetual bliss on yonder moon immediately after departing this life, that they seem to have had no fear of death. And because of their belief they placed this celestial body in a high position in their religion. All festivals were arranged in accordance with its phases, and to them its brilliancy radiated from the lives of the happy souls who had gone to dwell thereon.

MOONLIGHT IS MERELY REFLECTED SUNLIGHT

In spite of the many curious references to the moon by poets and other writers, the early scientists seem to have had some correct ideas about the relation of the moon to the sun and to the earth. The founder of Greek astronomy was Thales, who must have had a fairly accurate knowledge of the movements of the sun and the moon for he is said to have been the first man to predict an eclipse of the sun. Thales correctly taught his followers that the moon borrows its light from the sun.

Since moonlight is merely reflected sunlight it is obvious that the light we receive from the moon must be very much inferior to the light from the sun. In fact, sunlight is about 465,000 times as bright as moonlight. If the entire dome of the sky were filled with full moons the total amount of light received on the earth would be only about one-fifth of that received from the sun. The sun throws more light on the earth in one second than the moon gives us in a month.

Of course everyone now understands why sunlight is brighter than moonlight but this explanation was not so obvious to primitive peoples, who looked upon the moon as a crystalline sphere with the property of emitting light similar to sunlight but not

quite so bright. Some of them may have been like the child who said, "The sun is brighter than the moon because the sun shines in day time and the moon at night."

The moon is usually referred to as the "companion" of the earth. The truth of this statement becomes apparent when we learn that this heavenly body is only 238,000 miles away. This is an extremely short distance in comparison with the enormous intervals of space which separate us from other members of the sun's family, being only about ten times the distance around the earth. An airplane, traveling at the rate of 200 miles an hour, could fly this far in about seven weeks. No other heavenly body (except meteors) ever comes this close to us. For a certain reason which we shall not attempt to explain here the moon usually appears much larger when rising or setting than when higher in the sky, although when it is on the horizon it is actually 4,000 miles farther from us than when it is on the meridian.

THE UNITED STATES WOULD COVER ONE-FOURTH OF THE MOON

How large is the moon? Perhaps you may answer that the full moon and the sun are the same size. They do appear to be about the same size but we must remember that the sun is 93,000,000 miles away while the distance to the moon is only 238,000 miles. Since the sun is 400 times as far away as the moon, it must be about 400 times as large in order to look the same size. The diameter of the moon is only 2163 miles, about one-fourth of the diameter of the earth. At the rate of 280 miles an hour, a speed which will soon be exceeded by our commercial airplanes, we could fly completely around the moon along its equator in twenty-four hours.

The surface area of the moon is only one-fourteenth of the surface of the earth, being about four and one-half times the size of the United States. If the surface of the moon were divided into five zones like we have on the earth and the United States were cut into strips of the width of the lunar torrid zone and placed end to end, it would reach more than half way around the moon.

Although the moon is much smaller than the earth, no other world has a satellite that is so large in comparison with its parent world. Several of Jupiter's moons are larger than ours but Jupiter has more than 700 times the surface area of its largest moon. The inhabitants of Mars must enjoy watching the antics of the earth and its moon, which to them appear as a brilliant double star.

Since the moon is so much smaller than the earth we would expect gravitation at its surface to be less than at the surface of the earth. In fact, the force of gravity on the moon is only about one-sixth as strong as on the earth so that a man who weighs 150 pounds would weigh only twenty-five pounds if he should move to the moon. If he can jump four feet off the ground, he could jump six times as high on the moon, and with the same energy he could carry six times as heavy a load on the moon as on the earth. The weakness of gravity on the moon may account for the enormous scale of its surface structure.

THE MOON MAKES A TRIP AROUND EARTH IN ABOUT TWENTY-SEVEN DAYS

The varying positions of the moon in the sky must have attracted the attention of everyone. Tonight it may appear to be very close to some particular star but tomorrow night it will be about thirteen degrees east of that star. This is due to its monthly revolution around the earth in about twenty-seven and one-third days.

Since the moon makes the complete circuit of 360 degrees in twenty-seven and one-third days its average daily motion among the stars must be about thirteen degrees. The moon does not move at a uniform rate. As it swings around the earth, held in place by the invisible chain of gravitation, it must move in such a way as to obey Kepler's Law of Areas, which applies to the motion of every moon around its primary world as well as to the movements of the planets about the sun. Since its orbit is not a circle, but an ellipse, the moon is sometimes closer to the earth than at other times and the closer it is the faster it moves.

While the moon is making its monthly trip around the earth

at the tremendous speed of 2300 miles an hour the earth itself is revolving around the sun with a speed about thirty times as great and is taking the moon with it. Thus the moon not only revolves around the earth but it also revolves around the sun in a rather complicated curve, crossing the orbit of the earth every two weeks. The radius of the earth's orbit is about 400 times that of the moon, so that if we should represent the orbit of the earth by a circle with a radius of thirty-three feet the moon would deviate from this circle only about one inch.

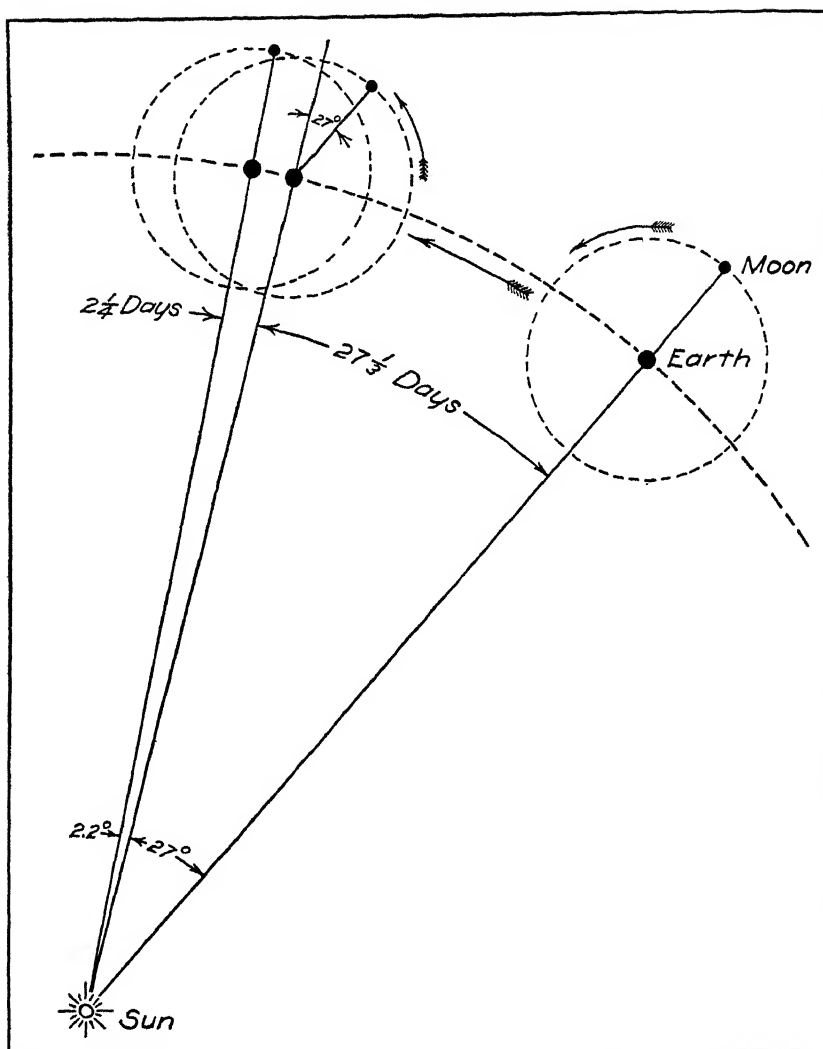
MOON FAILS TO RISE ONE DAY IN EVERY MONTH

Nature has so regulated the motion of the moon that it makes one complete circuit around the earth eastward from a given star back to the same star again in twenty-seven and one-third days. This is known as the sidereal period of the moon because it is determined by the stars. But nature has also given the earth a motion about the sun which carries it about twenty-seven degrees eastward during these twenty-seven days so that the moon must have time to move the twenty-seven extra degrees before it can get back to the same position relative to the sun.

Since the moon is moving about thirteen degrees a day it will cover this extra distance in about two days after it has completed its circuit around the earth. In other words, if the moon is in line with the earth and the sun this evening it will not be back in the same position again for about twenty-nine and one-half days. This is known as the synodic period of the moon and is the length of time from new moon to new moon—a natural period of time which many early peoples used to regulate their calendars.

If we read in ancient literature that a man lived 969 "cycles" we are not sure how old he was, because we do not know what cycle was meant. If we interpret this to mean that he lingered on the earth long enough to make 969 trips around the sun then he certainly did make a record. But if he merely lived long enough to see the moon make 969 trips around the earth he must have died at the ripe old age of four score years.

Let us suppose that the moon is on the meridian tonight at



After the moon has made a circuit around the earth it gets back in line in two and a quarter days, so that the lunar month is about twenty-nine and one-half days.

ten o'clock. Then tomorrow night at ten o'clock its position among the stars will be thirteen degrees east of its present position, because of its motion around the earth. But by tomorrow night the sun will have moved about one degree eastward among the stars, so that the moon will be twelve degrees farther east of the sun tomorrow night than it is tonight and at ten o'clock it will lack about twelve degrees of being on the meridian.

The moon will not cross the meridian until the earth has had time to rotate through this angle of twelve degrees. The earth rotates through one degree in slightly more than four minutes. Thus the moon must cross the meridian on the average about fifty-one minutes later every day, so that there is one day in every month when the moon does not rise and also a day when it does not set. For example, if it rises at 11:30 P.M. on Sunday it will not rise again until about 12:21 A.M. on Tuesday. The interval of fifty-one minutes is merely an average. The actual retardation of the moon varies from thirty-eight minutes to sixty-six minutes.

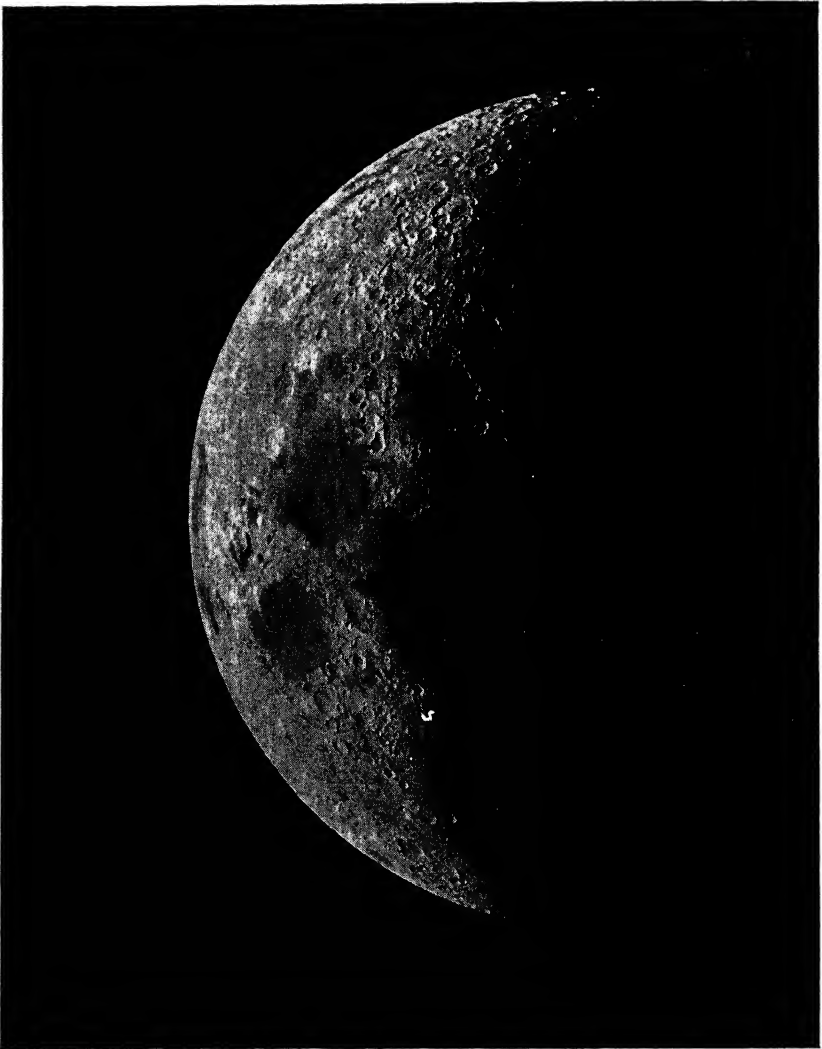
THE MOON GOES THROUGH ITS PHASES EVERY TWENTY-NINE AND ONE-HALF DAYS

As the moon goes around the earth the relative positions of the earth, the moon and the sun are constantly changing. When the moon is between the sun and the earth we cannot see it because the sun is then shining on the side that is turned away from us. A few days later, however, the moon will be found several degrees to the east of the sun and a slender strip of our side will be illuminated which we see as a thin crescent moon near the western horizon immediately after sunset. On each succeeding evening we will find the moon about thirteen degrees farther east and more and more of our side becomes illuminated, until the moon is one week "old" when the entire western half of our side is visible. Since we really see only one-fourth of the moon's surface at that time we speak of this phase as "first quarter." The moon is then ninety degrees east of the sun and will be found near the meridian at sunset.

As we watch the moon night after night we will see our side gradually become flooded with light until it is completely illuminated. The phase which occurs when the moon is two weeks old is known as "full moon." Then the moon is 180 degrees east of the sun and will rise about sunset. As the moon continues its eastward motion its bright side gradually shifts toward the east, leaving its western half obscured by darkness until, at the end of the third week, we can see only the eastern half of our side. This phase is known as "third quarter" and the moon will then

rise about midnight, being only about six hours ahead of the sun.

The illuminated part of our side of the moon then gradually "wanes" as it approaches the sun until, as a thin crescent moon



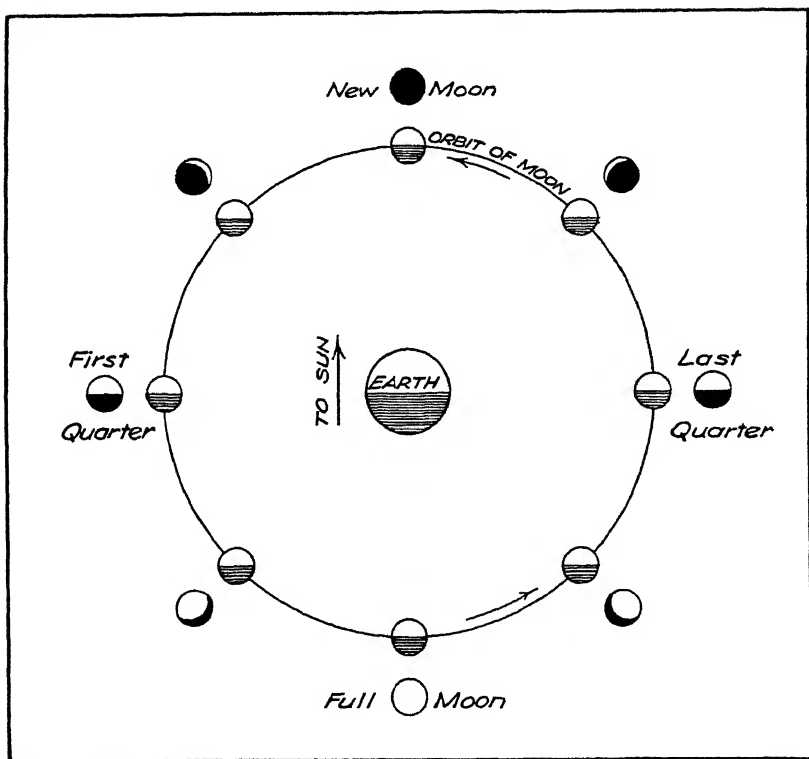
The 5-day moon.—Photographed at Yerkes Observatory.

near the eastern horizon, it becomes lost in the light of dawn. After another day or so it will re-appear on the eastern side of the sun as "new moon" and will then gradually pass through all of its phases again. One often hears such a remark as "The moon

changes next Wednesday." This is, of course, meaningless, since the line between daylight and darkness on the moon slowly shifts across its face and the apparent shape of the moon will change no more next Wednesday than next Tuesday or next Thursday.

CHANGING POSITIONS OF MOON ARE RESPONSIBLE FOR ITS PHASES

Why does the moon exhibit phases? The answer to this question is obvious when we recall the fact that the moon gives no



The side of the moon toward the sun is always light and the other side dark. But we do not always see all of the bright side. Hence the phases.

light of its own but merely shines by reflected light. We can see the moon up in the sky for the same reason that we can see the bird up in a tree—because the sun furnishes the light. When

the shadow of the moon falls across the lunar landscape a part of its surface becomes invisible to us, just as the bird cannot be seen at night after the shadow of the earth has fallen upon the tree. If the moon could shine by its own light, as the sun does, it would be "full" all of the time. However, as nature has arranged things, we see only that part of our side of the moon upon which the sun happens to be shining.

The mere fact that the moon shines only by reflecting the light of the sun will not account for the fact that from the beginning of time it has exhibited phases which change from night to night and afforded early travelers and shepherds their first means of measuring time. The motion of the moon around the earth is responsible for its phases and if some Joshua should stop the moon when at "first quarter" it would exhibit that phase forever.

And now to give a direct answer to the question. The moon shows different phases on different evenings because it gives no light of its own and is visible only when and where the sunlight happens to strike it, and because the relative positions of the earth and moon with reference to the sun, which is the source of light, are constantly changing.

Because of their ignorance of astronomy, artists sometimes paint beautiful pictures of sunsets with the crescent moon upside down and writers make the moon perform all kinds of curious antics. A famous author tells us that immediately after sunset "a pale young moon was getting up in the heavens." The new moon would appear in the western sky just behind the sun and would be going down instead of up. Another writer says, "The time was dusk of evening and very low in the east a half moon hung." At the time of first quarter the moon would be "very low in the east" about noon and at the time of last quarter it would be in this position about midnight.

THE FULL MOON IS ALWAYS OPPOSITE THE SUN

Everyone has noticed that the full moon shines all night long. At the time of full moon the earth is between the moon and the sun so that these two heavenly bodies must appear in opposite parts of the sky. Thus the full moon will set in the west just

as the sun rises in the east and as the sun sinks below the western horizon the full moon will climb up into the eastern sky reaching the meridian at midnight when the sun is on the same meridian on the other side of the earth. If the sun is north of the equator the full moon will be about the same distance south of the equator and if the sun is south of that circle then the full moon is at an equal distance north of it.

Why does the full moon climb so high in the sky in December and January? This is also due to the fact that the full moon is opposite the sun. During the winter the sun is south of the equator and crosses the meridian at a very low altitude so that the full moon is then north of the equator and crosses the meridian at its highest possible altitude. During the long arctic nights the inhabitants of the Polar regions are able to take full advantage of the light of the moon because it is above the horizon most of the time from first quarter to last quarter.

As we watch the full moon float across the sky we sometimes imagine we would enjoy a trip to our companion world in an airplane or some kind of a rocket. Of course we must first invent a machine that does not require air to support it or we will have trouble when we get out of the atmosphere of the earth. It will then be necessary to jump off one ball (earth), which is flying at the rate of about 70,000 miles an hour, onto another one (moon), which is moving 2300 miles an hour around the flying ball from which we jumped. This will be quite an acrobatic stunt and it is obvious that our attempt to land on the moon will be quite interesting. Will we chase the moon around in its orbit until we can get up enough speed to overtake it or will we get in its path and let it hit us?

THE MOON ALWAYS KEEPS THE SAME FACE TOWARD THE EARTH

As the earth proceeds on its annual journey around the sun it rotates at a constant rate in this same direction. Likewise the moon while making its monthly trip around the earth also rotates in the same direction in which it revolves. The earth spins on its axis many times while making one revolution about the sun, but the moon rotates on its axis exactly once in each

sidereal month. The astronomers have studied the moon during thousands of revolutions about the earth and every month its rotation period is exactly (not approximately) the same as its period of revolution around the earth.

The equality of the periods of revolution and rotation of the moon could hardly be accidental, for some of the satellites of other planets behave in the same way. This condition must have been brought about by natural forces, but what these forces are has not yet been determined. It has been suggested that the attraction of the earth raised tides on the moon before our satellite assumed a solid state—the moon now raises tides in our oceans—and that these tides gradually retarded its rotational speed until it now rotates only once during each trip around the earth.

The moon always keeps the same face toward the earth. We in the twentieth century see exactly that part of the surface of the moon that Galileo revealed to the world when he built his first telescope in 1610. The moon goes around the earth like the little boy goes around the elephant at the circus—looking straight at him all of the time. Our satellite then has two sides—the front side, all of which is visible at every full moon, and the back side, which no human being ever saw.

It is sometimes difficult to understand how the moon can actually rotate and still keep the same face constantly toward the earth. This difficulty arises from the fact that we are looking at it from the earth. We could see this rotation if we could only get off of the earth.

Let us imagine that a small ball, with one side painted white, is firmly attached to the outer edge of a revolving phonograph record. The marked side of the ball will be presented successively to every point of the compass and the ball will make exactly one rotation (around an imaginary axis) every time the record turns around.

A DAY ON THE MOON IS ALMOST A MONTH

Although the moon constantly keeps the same face toward the earth, its inhabitants—if there are any—have a succession of night and day just as we do, but their days are much longer

than ours. As a result of its slow rotation the length of a day on the moon is equal to twenty-nine and one-half of our days—one synodic month. The sun rises and gradually climbs to the meridian which it reaches in about a week and after another week it sinks slowly below the horizon and then is invisible for the next two weeks.

Some people find it a little difficult to understand how the inhabitants of the moon can have two weeks of daylight followed by two weeks of night. Perhaps this will be made clear if we contemplate the behavior of the sun as seen from a position of observation on the surface of the moon. Let us assume that we are living near the center of the moon as seen from the earth and let us begin when the moon is at first quarter. Since we are on the terminator—the line that separates daylight from darkness on the moon—the sun will be just rising. It will lift itself very slowly above the horizon and will climb up into the sky a distance about equal to its own diameter every hour.

As the sun slowly climbs toward the meridian the temperature of the surface of the moon will rise very rapidly. After about seven of our days—at full moon—the sun will finally reach the meridian, having poured its terrific heat continuously upon the surface of the moon for 178 hours. At the time of lunar noon the surface of the moon directly under the sun and unprotected by an atmosphere will have a temperature of 250°F .—higher than that of boiling water. During the next week the sun will gradually fall toward the horizon and set when the moon is at third quarter. Meanwhile the temperature of the moon will gradually diminish and, during the long lunar night of fifteen days, it will probably reach a temperature of -150°F .—much lower than any with which we are familiar upon the earth. Unfortunately the moon has no atmosphere to protect its surface from the glaring rays of the sun or to hold the sun's heat after that celestial furnace has disappeared below the horizon.

WE ACTUALLY SEE ABOUT FIFTY-NINE PER CENT OF THE MOON'S SURFACE

The statement that the moon always keeps the same face toward the earth is not strictly true, for its movement about the

earth is not quite like that of a fixed ball on a phonograph record. There is no rigid connection between the earth and the moon and the rotation of our satellite is absolutely independent of its orbital motion. It rotates at a uniform rate but it must move around the earth in such a way as to obey Kepler's Law of Areas. Sometimes it moves faster than at other times but its speed is so regulated that its circuit around the earth and its rotation on its axis will be completed at exactly the same instant. This makes it possible for us to see a few degrees around the eastern edge of the moon at one time of the month and a few degrees around the western edge at another time.

The axis of the moon is inclined at an angle of about six and one-half degrees to its orbit so that we can see alternately about six and one-half degrees beyond its north pole and its south pole. Again, when the moon is rising we can look over its western edge about one degree, and we can see an equal area beyond its eastern edge when it is setting.

These small oscillations—known as “librations”—make it possible for us to see a little more than one-half of the moon's surface. In fact, about fifty-nine per cent of its surface can be seen at one time or another leaving only forty-one per cent which is never visible to us at any time. Here is some unexplored and uncharted territory only 238,000 miles away.

The inhabitants of that part of the moon—if there are any—must be entirely unaware of the existence of the earth unless they have learned about our world from their friends on our side of the moon or have themselves done considerable traveling. They certainly could never have seen the earth without leaving the back side of the moon and paying a visit to our side of their world. To those who live on our side the earth would appear fixed in the sky, except for a slight oscillation, moving only as they move about on the moon. There would be no rising and setting of the earth as seen from the moon.

THE EARTH SHINES ON THE MOON

When we realize that moonlight is merely second-hand sunlight, that is, sunlight which strikes the moon and is reflected to the earth, we naturally wonder if the sunlight that falls

upon the earth is not reflected to the moon. In other words, does not the earth also shine on the moon? This is certainly a very natural question and one that is easily answered. The earth does reflect sunlight to the moon and, since it is much larger than the moon and is frequently surrounded by white clouds which have a very high reflective power, earthlight on the moon is much brighter than moonlight on the earth.



The earth-lit moon.—Yerkes Observatory.

Everyone has seen the earth shining on the moon. Look at the moon the next time it is "new" and you will see a thin crescent in the western sky and then you will discover the faint outline of the rest of the moon, or, as we usually say, you see "the old moon in the new moon's arms." Perhaps you have often wondered what caused this interesting phenomenon. The crescent is simply that part of our side of the moon on which the rays of the sun are falling at that time. The rest of our side of the moon is dimly visible because the earth is shining on it. At that particular phase of the moon the earth is shining so brightly that the moon is plainly visible when as a matter of fact it should be completely dark.

The earth borrows its light from the sun, so that for an observer on our side of the moon the earth would exhibit phases similar to those of the moon except that when the moon is "new" the earth would be "full." The lunar inhabitants have

an earth in their sky—about four times as large as our moon and about eighty times as bright—which remains fixed except for a slight oscillation and goes through all of its phases in the course of a single lunar day and night. For an observer in the center of our side of the moon the earth would go from first quarter to “full earth” and then to last quarter during the two weeks of lunar night and would furnish a fair substitute for the invisible sun. Imagine the interest that would be aroused by the eternal parade of our continents and oceans across the face of the earth.

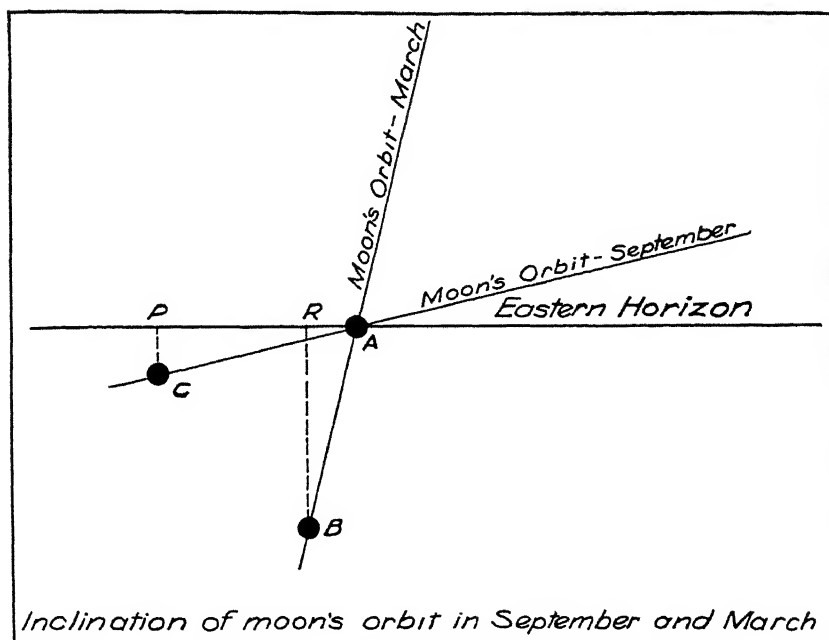
THE HARVEST MOON RESULTS FROM SMALL INCLINATION OF MOON'S ORBIT

Everyone has noticed how much moonlight we have in September when the full moon appears to rise at about the same time every evening. Here again nature seems to have to come to the assistance of man by lengthening the days so that he can get his crops put away before the bad weather sets in. Let us investigate the cause of this apparent retardation in the motion of the moon.

We have defined the celestial equator as an imaginary circle in the sky, every point of which is ninety degrees from the two celestial poles. This circle passes through the east and west points of the horizon and slopes toward the south at a constant angle which is determined by the latitude of the observer. The ecliptic crosses the equator at the two equinoxes at an angle of twenty-three and a half degrees, and six of the constellations of the Zodiac are north of the equator and the other six lie south of it.

The orbit of the moon makes an angle of about five degrees with the ecliptic. Consequently the moon's celestial path does not always pass through the east point, neither does it make a constant angle with the horizon. Sometimes it is almost perpendicular to the horizon so that, if the moon rises at six o'clock this evening, its daily eastward motion of thirteen degrees will cause it to be so far below the horizon tomorrow evening at six o'clock that the rotation of the earth will not bring it above the horizon for more than an hour.

During September this angle is very small so that, although the moon moves during the day a distance of approximately thirteen degrees eastward along its orbit, it will be found the next evening only a few degrees below the horizon, so that the rotation of the earth will bring it above the horizon in a much shorter time than at any other season of the year. It is for this reason



that, at this time of the year, the full moon rises just a few minutes later every evening, so that we have more moonlight evenings in September than in any other month. This explains what we call the "Harvest Moon." This interval is also somewhat reduced at the time of the October full moon, although it is not quite as marked as in September. The October moon is called the "Hunter's Moon."

MODERN TELESCOPES REDUCE MOON'S DISTANCE TO 100 MILES

When we turn one of our big telescopes on the moon, we bring that celestial body down so close to us that we feel that we can

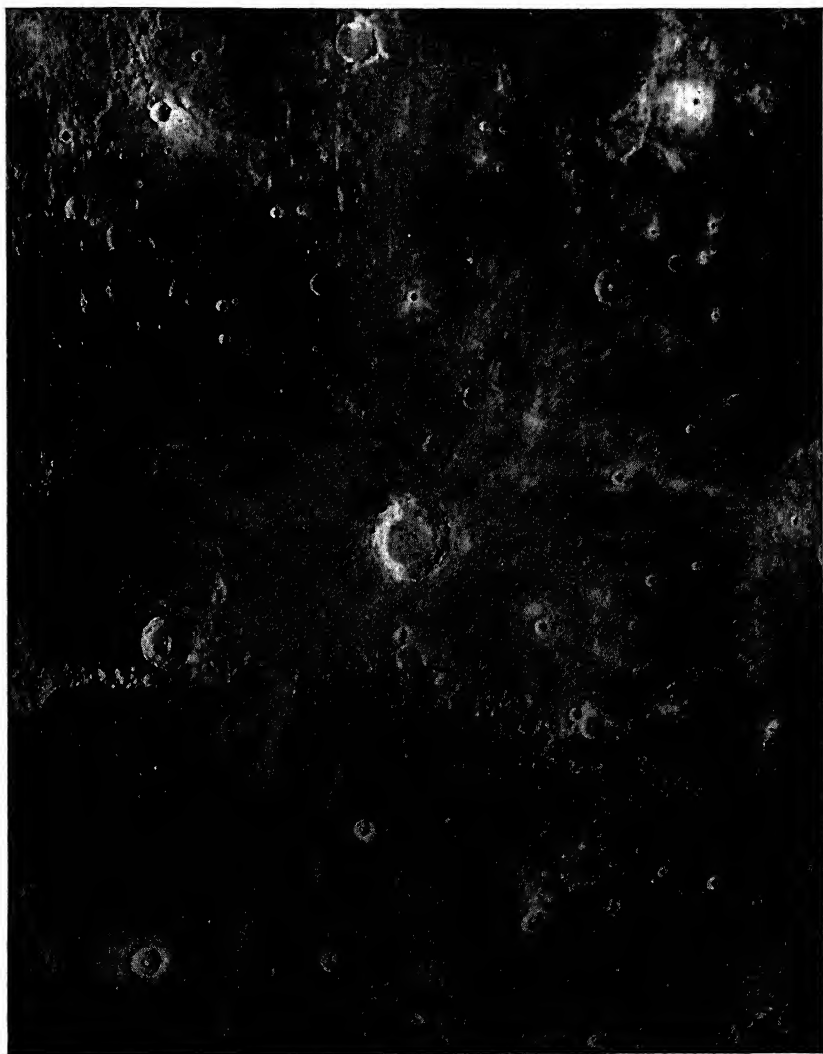
almost reach out and touch it. In fact, it is said that the giant telescope on Mount Wilson in California brings our companion world to within one hundred miles of the earth. Although to the naked eye the moon appears the same size as a silver dollar at a distance of ten feet, this 100-inch telescope reveals every feature of the lunar landscape that would be visible to the unaided eye at a distance of 100 miles. We could see rivers, lakes and forests and even great cities, if any existed, but of course not highways, railroads, or buildings. Other telescopes now being constructed will probably reduce this distance considerably more, so that we have hopes of being able to study the surface of the moon at close range in the near future.

Although the moon is brightest when it is full this is not the best time to study its features through a telescope. At this time the earth is between the sun and the moon and there are no shadows to throw the lunar features into relief because the light is coming from directly behind us. The most satisfactory results are obtained by studying lunar craters and mountains as they come into view along the terminator—the line which separates daylight from darkness on the moon. On this part of the moon the day is just beginning and the mountains cast long shadows across the lunar landscape. If you have access to a small telescope, turn it on the moon soon after first quarter and some of the most interesting lunar features will be found along the terminator.

As we look across the surface of the moon, from one side to the other, we see many very tall mountains whose shadows are outlined very distinctly on the surrounding landscape because of the absence of atmosphere. If we wish to compute the height of any particular mountain we must first measure the length of its shadow and then the result follows from a simple mathematical calculation. About 1100 lunar mountains have been measured, six of which are more than 20,000 feet high. The highest of all lunar peaks, which has been very properly called Newton, is approximately 24,000 feet in height.

THERE IS NO AIR OR WATER ON SURFACE
OF MOON

One day Galileo, the great Italian astronomer, heard about a wonderful instrument made by a Dutchman that would magnify distant objects and he immediately built one for himself. His telescope, crude as it was, attracted the attention of everyone by



The region of the moon near Copernicus, photographed with 100-inch telescope.—Mount Wilson Observatory.

making it possible to see ships on the ocean several hours before they entered the harbor. Galileo first studied the moon through his telescope and announced that this heavenly body was not a smooth crystal sphere but that it was covered with mountains and valleys like the earth. He pointed out that "the old moon in the new moon's arms" was due to earth-light which originated on the sun and was reflected back to the moon after striking the earth.

The surface of the moon may be very clearly seen through a large telescope not only because of its relative nearness to the earth but also on account of the absence of atmosphere. There is no air, and consequently no water, on the moon. There are no lunar clouds to intervene between us and the particular feature in which we may at the time be interested. No lunar rainstorms can obscure the peak of some lofty mountain just at the moment we wish to measure its height. A traveler on its surface would not be exposed to winds and storms, neither would he be protected from the glaring sunlight by floating clouds. There is no erosion on its surface so that its mountain peaks stick up into the sky like church spires just as they did ages and ages ago.

Apollo would drive his sun-car into the sky without his advent being announced by the rosy dawn. Gorgeous sunsets and twilight would be unknown and the stars almost up to the very edge of the sun would shine brightly in the daytime out of a black sky.

The moon probably had an atmosphere at one time, especially if it were once a part of the earth, but the force of gravity on its surface is so weak that it was not able to hold it. The large planets, Jupiter and Saturn, are able to retain atmospheres of much greater density than smaller worlds such as the earth and Venus. In fact the smallest planet, Mercury, appears to have lost its atmosphere entirely. If the moon ever had an atmosphere it lost it before Galileo invented the telescope because we can find no traces of its presence.

DISAPPEARANCE OF STARS BEHIND MOON PROVES ABSENCE OF ATMOSPHERE

How do we know that the moon has no atmosphere? We are convinced of the absence of an atmosphere because of several

well established facts. We have studied the surface of the moon for many years through large telescopes and no trace of an atmosphere has ever been found, every lunar feature presenting a distinct, clear-cut appearance at all times. Objects along the edge of the moon can be seen as clearly as those in the center. Photographs taken at the same lunar phase always look exactly alike. This would not be the case if there were any clouds floating in an atmosphere around the moon. Planets such as Mars, Venus and Jupiter, which have atmospheres of considerable density, do not exhibit permanent clear-cut features.

The moon frequently passes between us and a star and, in every instance, the star disappears suddenly behind one limb of the moon and re-appears just as suddenly on the other side after the moon has passed over it, just as if its light were supplied by an electric current which was turned off and then turned on again. If the moon had an atmosphere we would expect the star to fade out gradually rather than to disappear suddenly. When Venus passes over a star the light from the star becomes dimmer and dimmer and is finally extinguished when it passes behind the solid part of the planet. After a while the star can be seen shining dimly through the atmosphere on the other side of the planet and it then gradually regains its former brightness.

If the rays of light from the star were forced to penetrate a lunar atmosphere they would be refracted (curved) toward the moon so that we would actually see the star after it had gone behind one limb of the moon and before it came out on the other side, which would reduce the time the star was hidden from view. Now we know the diameter of the moon and how fast it is moving so that we can compute the length of time required to pass over any given star. The computed period always agrees with the observed period so that there can be no refraction. During an eclipse of the sun the limb of the moon is sharply defined against the surface of the sun and there is no encircling ring of light such as we might expect from a lunar atmosphere.

THERE ARE MOUNTAINS AND OCEANS ON THE MOON

What could have been more natural than for Galileo and his followers, immediately after the invention of the telescope, to turn this little instrument on the moon? Although Galileo's telescope magnified only thirty-three times it brought out many details of the lunar surface that had never before been clearly seen by man and, instead of talking about "The Man in the Moon" and "The Woman in the Moon," the astronomers began to pick out certain well defined details on the lunar surface and assign names to them.

On any good lunar map are more than a thousand mountain peaks, several of which are more than 20,000 feet high, and quite a few dark spots which are called seas and oceans. We call them seas because when they were first discovered they were supposed to be bodies of water, but they contain no water at the present time for there is no water anywhere on the moon. In fact, the surface of the moon seems to be so dry that it has cracked open and many immense canyons of unknown depth extend across the lunar landscape.

We can understand why the lunar mountain ranges were called Alps, Apennines, etc., but it is a little difficult to figure out where they got the names for the different oceans. On any good map of the moon we will find the Sea of Clouds, the Sea of Cold, the Sea of Crises, the Bay of Dew, the Lakes of Dreams, the Sea of Fertility, the Sea of Humor, the Sea of Nectar, the Bay of Rainbows, the Sea of Serenity, the Sea of Showers, the Ocean of Storms, and the Sea of Tranquillity.

As man improved his telescope he began to see details on the moon's surface that were much smaller than lakes, oceans and mountain ranges. These features he named after leading scientists such as Archimedes, Copernicus, Gassendi, Kepler, Newton and Tycho. This practice has been continued up to the present time so that most of our noted astronomers will have their names preserved for posterity on the maps of the mountainous features of the moon. Our side of the moon has been very carefully mapped and every mountain, every sea, and every characteristic feature has a name. In fact, the maps of our side of the

moon are said to be more accurate than those of certain parts of the earth.

LUNAR CRATERS ARE OF UNKNOWN ORIGIN

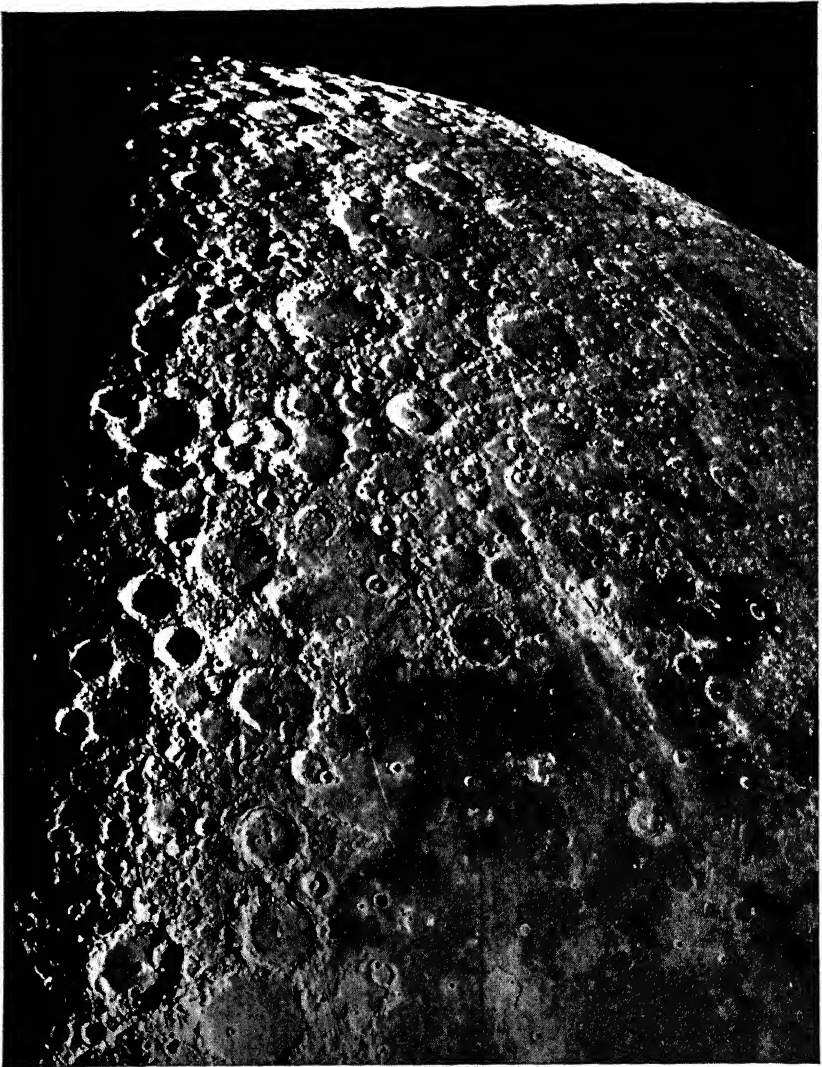
Some sections of the moon are literally covered with craters which resemble our extinct volcanoes, more than 500,000 being visible through our powerful telescopes. Although the largest craters on the earth are six or seven miles in diameter, we find many lunar craters with diameters of more than twenty miles and a few of the largest measure more than one hundred and fifty miles in width. The average lunar crater is approximately circular and is surrounded by a ring of mountains which sometimes rise to a height of 20,000 feet. Frequently a group of peaks several thousand feet high will be found in the center. The region near the South Pole of the moon is rougher and more picturesque than the roughest portion of our own Alps.

Several theories have been proposed to account for the numerous ring formations—craters—that today exist on the moon, and it will probably be some time before scientists can agree on the hypothesis that seems to best fit conditions as we find them on the lunar surface. There is certainly no such agreement today. Some will argue that these craters are the result of volcanic action ages ago but volcanoes require air and water and there are certainly no volcanoes on the moon now and besides such a theory could hardly account for craters a hundred and fifty miles in diameter.

Many argue that these ring formations resulted from the fall of meteors upon the moon long before its surface had completely solidified and call our attention to the fact that on the moon are to be found many overlapping craters such as would have resulted from such a bombardment, but they are immediately reminded of the fact that all of these craters are ring-shaped like ripples on water and they are asked how such an enormous number of meteors could strike the moon without at least a few of the craters having an oblong appearance. Surely all of these meteors did not fall "straight down" upon the moon's surface.

Others argue that the moon is merely an extinguished sun

which, in ages past, was much larger than it is today and very eruptive. According to this hypothesis the moon is merely the inner core of a small extinguished sun. Many objections can be



Southern portion of moon at last quarter. Photographed with 100-inch telescope.—Mount Wilson Observatory.

raised to this theory and the search for information that will explain the peculiar mountainous features on the moon's surface is still a free-for-all.

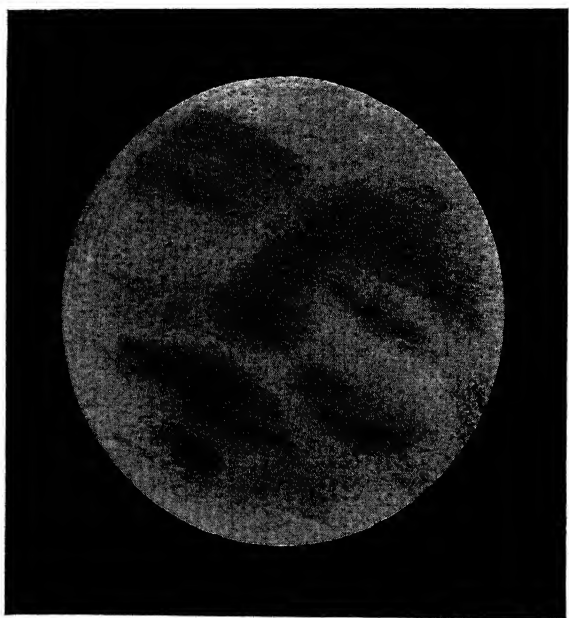
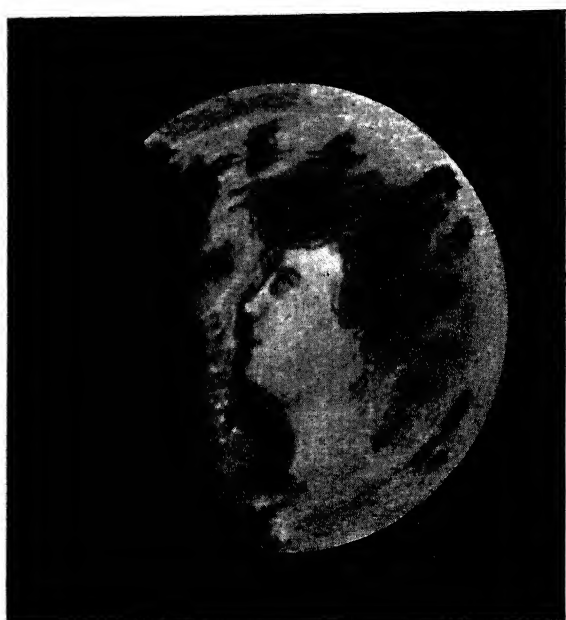
A MAN AND A WOMAN MAY BE SEEN ON THE MOON

Have you ever seen the Man in the Moon? Of course you have. Certainly there is no one who does not recognize his smiling face as he looks down upon us across 238,000 miles of empty space. Of course we realize that the Man in the Moon is merely an optical illusion which is due to the shadows on the moon, but his eyes, nose, mouth, and chin are very plainly visible in the full moon when it is rising. They are very prominent in the Harvest Moon. However, we find among almost all ancient peoples stories about a man who was banished from the earth to the moon on account of improper conduct and who then became the Man in the Moon.

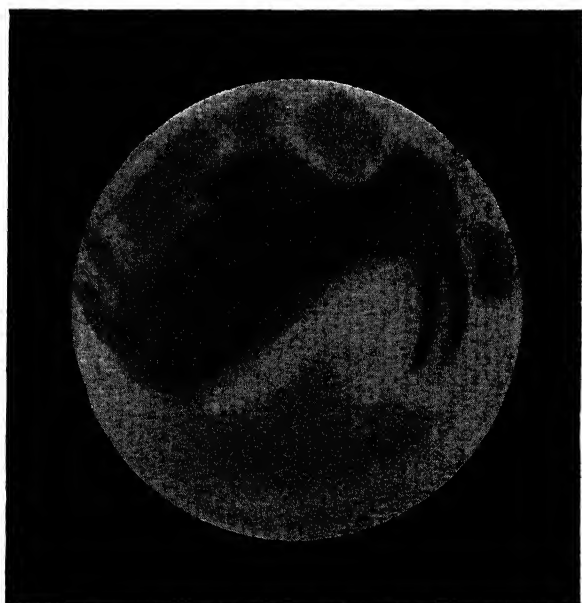
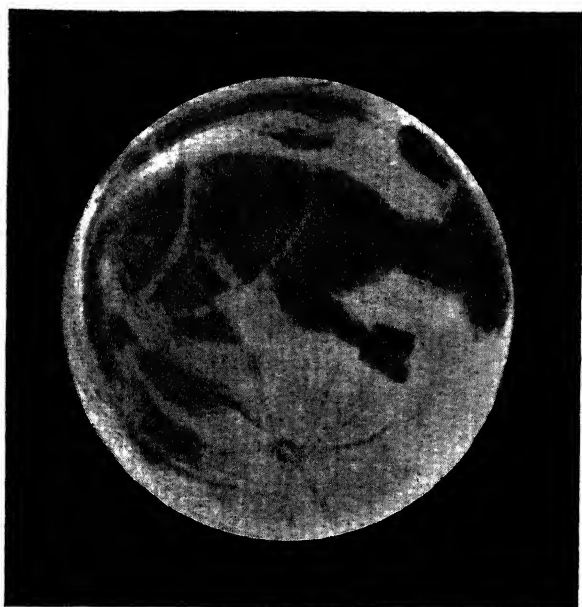
The Man in the Moon would be very lonesome, in fact he would probably not remain on that dreary world very long, were it not for the companionship of the Woman in the Moon. There is a woman in the moon and she is easier to see than the Man in the Moon if you look for her at the proper time of the month. When the moon is about twelve days old her face is plainly visible.

Almost every one has read of the way in which early peoples made use of this mythical man and his wife in their attempt to explain the eclipses of the moon. It seems that this quaint old couple got along very well together but that at more or less regular intervals the wife found it necessary to sweep the cobwebs out of her house and in so doing she raised a great cloud of dust which gave the moon a reddish-brown color for several hours.

A careful study of the moon, combined with a very vivid imagination, will reveal the presence of another woman in the moon who apparently spends her time reading a book, the contents of which have not yet been revealed by our most powerful telescopes. There is also a rabbit in the moon which, although forced to stand on its head all of the time, seems to be able to balance itself in this position indefinitely. Here again distance lends enchantment, for when we attempt to study these lunar fantasies more closely through the telescope they disappear altogether and we realize that we are looking at what appears to be merely a bare rock.



Lunar fancies.

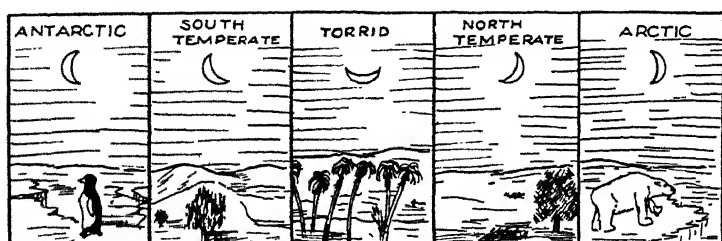


Lunar fancies.

THE MOON DOES NOT INFLUENCE THE WEATHER

What influence does the moon have on the earth? There are probably more superstitions with reference to the moon than any other heavenly body. Many people insist upon allowing the moon to regulate the weather and "wet moons" will be found in every locality. When the new moon lies flat on its back the water cannot run out so that we need not expect any rain, but when the crescent stands on end it is sure to pour out its water on the earth. This belief is found everywhere among unthinking people who do not realize that there is not a drop of water on the moon. It is too bad that so few people understand that the horns of the crescent moon always point directly away from the sun and that their direction depends upon certain definite laws and can be figured out years in advance.

It is interesting to note that the angle at which the crescent moon is tilted is just the same for all people living in the same



THE ANGLE AT WHICH THE MOON IS TILTED
DEPENDS UPON THE ZONE FROM WHICH IT IS OBSERVED

latitude. Consequently, if the crescent moon brings a rain to one locality then we may expect it to rain all over a belt which completely surrounds the earth—crossing America, Europe, Asia, and even the deserts of northern Africa. Following this argument to its logical conclusion we are forced to admit that in the Torrid Zone, where the new moon always lies on its back, rain must be very rare, while in the arctic and antarctic regions, where the crescent moon always stands on end, rain and snow must be more frequent than on any other part of the earth. In the North Temperate Zone the horns of the crescent are turned upward in the spring so that we should have very little rain during that

season, but in the fall the new moon is tilted so that rain should then be plentiful.

During a continued drought one sometimes hears a remark such as "Never mind, the moon changes next Wednesday and we will certainly have rain then." Of course such a statement is perfectly absurd. How could a change of the moon affect the weather? The moon is changing all of the time and it would be just as reasonable to divide the lunar month into three or even five parts as into four parts. Of course the moon has absolutely nothing to do with the weather.

LUNAR SUPERSTITIONS ARE COMMON TO ALL PEOPLE

Many lunar superstitions have been handed down from generation to generation. We are told that rheumatism is more painful at full moon, fish bite best at full moon, frost at full moon will do no damage, hickory bark will peel at full moon, if we deaden a tree at full moon the leaves die immediately, and that if we build a rail fence in the light of the moon the bottom rail will quickly decay. Some people believe that shingles that are put on a roof in the light of the moon will curl, while those laid during the dark of the moon will cause no trouble. We are advised to set our hens and to brand our cattle in the dark of the moon, but to do all of our butchering, to graft and prune our trees and to shear our sheep in the light of the moon.

There is no locality where these lunar superstitions are not prevalent. In one section of the country we learn that when the new moon appears in the west we must be sure to see it first over our right shoulder if we want to have good luck. In another locality we are told that if we see the new moon over our left shoulder and then make a wish, the wish will come true. However, before looking into the western sky we should be sure that the moon is not behind a tree from us, because bad luck is sure to overtake any one who sees a new moon through the limbs of a tree.

We are advised to have our hair cut at new moon if we want to be healthy and we are warned never to sleep with the moon

shining in our face if we wish to avoid insanity—perhaps due to the similarity of the words “lunar” and “lunacy.”

In a legal controversy over the possession of some cattle, an experienced cattleman recently testified that the brand on a calf is sure to enlarge with age if the calf is branded during the light of the moon. His statement was corroborated by several other cattlemen in an effort to prove that, although the brand on certain cattle whose ownership was disputed was much larger than the one ordinarily used, these calves had been branded in the light of the moon and that this enlargement was to be expected.

SOME LUNAR “SIGNS” ACTUALLY WORK

Some of the “signs” associated with the moon actually work, not because the moon happens to be in a certain phase or position, but for some other reason. For example, a heavy frost will occur on a moonlit night not because the moon is shining but because there are no clouds. There is one sure “sign” of rain that deserves special notice—a ring around the moon. A little reflection, however, will convince you that this ring is not around the moon but in the atmosphere of the earth and consequently the moon has nothing to do with it. It is true that the light from the moon shining upon the particles of water in the atmosphere causes this ring but any other brilliant light placed at the proper distance from the earth would have the same effect.

Some of us may smile when we hear about some curious superstition with reference to the moon. However, it would be very difficult to find any person who is not superstitious about something. We may refuse to allow the moon to affect our lives in any way and still believe implicitly in the weather prediction made by the ground-hog on the second of February. On the other hand, we may pay no attention to the weather on February second and we may even refer to the man who plants his potatoes in the moon as a “ground-hog astronomer” yet, after we have driven our automobile several thousand miles without tire trouble we will tell our friends about it and then “knock on wood.”

If you ask an astronomer what effect the moon has on the earth his answer will indicate clearly his belief that the moon

has absolutely no effect on the condition of our atmosphere. The moon does not tell us when it will rain and when it will not rain, or when it will be hot and when it will be cold. It is merely a satellite of the earth that was created about the same time as the earth but has dried up much more quickly on account of its very small size. It is moving around the earth subject to the same law that holds the planets in their orbits around the sun, namely, the law of gravitation. As the moon goes through its phases month after month it simply reminds the scientist that law still remains supreme in the universe.

THE MOON CAUSES THE TIDES

Perhaps you are asking, "For what purpose then was the moon created? What good does it do?" The answer is, "The moon gives us light at night, the moon measures time by its phases and the moon causes the tides in our oceans and rivers." The moon does affect the earth in two ways. It causes a slight variation in terrestrial magnetism and it also causes the tides. Of course the sun has something to do with the tides but the moon being much closer has a much greater effect than the sun. These two heavenly bodies by means of gravitation actually lift the water in our oceans and rivers and then the rotation of the earth causes the tidal wave to travel around its surface.

The great German mathematician Kepler guessed that the moon had something to do with the tides because the tides seemed to vary with the motions of the moon. Of course since no one had yet dreamed of the law of gravitation he was unable to determine what this connection really was. When Newton applied his law of universal gravitation to a study of the tides he was able to show that the attractive power of the moon actually lifted up the movable water on the earth and thus created the tides. He also called attention to the fact that the combined attractions of the sun and the moon would cause tidal waves of different heights at different times in the month. Here again lies another phenomenon of nature which is merely a direct consequence of the law of universal gravitation.

It is a well known fact that the time between two successive

transits of the moon across the meridian varies from twenty-four hours and thirty-eight minutes to twenty-four hours and sixty-six minutes, the average being about twenty-four hours and fifty minutes. Those who live on the seashore know that the tide comes in about fifty minutes later every day. Since the moon's passage across the meridian is retarded about fifty minutes every day it did not require much study on the part of astronomers to connect the moon and the tides. Consequently, the next time you stand on the ocean shore and watch the tidal wave roll in just remember that, although the moon may at the time be invisible, our little companion world is still on the job.

THE TIDES VARY WITH THE POSITION OF THE MOON

If the entire surface of the earth were made up of solid rock and dirt the tidal effect of the moon would not be noticeable. But three-fourths of its surface is water, which our companion world keeps pulling out of its proper place. At the time of new moon, or full moon, the sun and the moon are pulling together and we have the highest tides of the month—the spring tides. When the moon is at first quarter, or third quarter, the sun and the moon are pulling in opposite directions and we have the low tides—the neap tides. Their relative heights are in the proportion eight to three. When the moon is closest the tides are about twenty per cent higher than when she is farthest away. The highest tides of all happen when the new, or full, moon occurs at the time when the moon is closest to us.

If the earth kept the same face to the moon the tides would be permanent, but since the earth is rotating, the tidal waves travel westward. If the earth were covered with water that was deep enough, the tides would move with perfect regularity, but since the oceans are comparatively shallow and are separated by barriers of dry land, the tidal waves move in a very irregular fashion and do not remain directly under the moon.

In mid-ocean tides are usually between two and three feet high, but when the tidal wave strikes shallow water its height is increased and when it reaches the shore it may be twenty or

thirty feet high, depending upon the depth of the water and the configuration of the shore line. We sometimes have tides forty feet high in the Bristol Channel and it is said that tides of 100 feet have been reported in the Bay of Fundy. When the tidal wave reaches the mouth of a river it ascends the river at a rate which depends upon many factors. In the Amazon it is said to go up to an elevation of at least 100 feet above sea level.

Although the effect of the tidal wave is to lessen the speed of rotation of the earth and consequently to lengthen the day, the day does not actually become longer. There are other factors which tend to shorten the day so that the result of tidal friction even in a century is very small.

CHAPTER V

Signs and Wonders

SUN, MOON AND STARS WATCHED OVER PRIMITIVE MAN

PRIMITIVE man believed that not only the earth but also the entire universe was created for his pleasure and enjoyment. The earth furnished him a place to live and a means of livelihood, but the heavenly bodies also contributed to his comfort. Since he was the object of creation, the sun, moon and stars must have been placed in the sky for a definite purpose in some way related to him. He believed that every heavenly body was in some way interested in him so that his future career would be revealed if only he could learn to read the open book of the heavens. This desire for information resulted in that great fraud of the Middle Ages—astrology.

The sun kept man warm and by its daily motion from east to west and its annual motion among the stars provided him with two convenient units for measuring the lapse of time. The moon furnished him some light at night and went through a series of phases in regular order so that he might have another unit of time—the month—which was more convenient for many purposes than either the day or the year. Many peoples regulated their calendars entirely by the phases of the moon.

The sun, the moon and the five wandering stars—the planets—were always very closely associated with the welfare of man. They carefully watched over the human race, relieving each other every hour in a fixed order. Each day was named after the heavenly body that was on duty the first hour of the day so that there naturally arose another period of time—the week of seven days—which was provided not by nature but by the imagination of man himself. Even the fixed stars were placed in the sky

for the benefit of man. Sirius and some of the other bright stars were used to regulate his calendar, but every star in the sky, no matter how dim, had some influence on him, for otherwise there would have been no reason for its existence.

Even in the hymns of today we sing about the sun, the moon and the stars as if there was nothing else in the universe. We have all heard of the student who, after vainly trying to answer the questions on an astronomy examination, wrote on his paper the words of that familiar hymn, "Sun, moon and stars have I forgot, upward I fly."

PRIMITIVE MAN WAS TERRIFIED BY CELESTIAL "SIGNS AND WONDERS"

Ever since man has been on the earth he has watched the movements of the sun, the moon and the stars. These heavenly bodies appeared to him to be moving slowly in an orderly manner, furnishing him light and heat and even revealing his future career if only he were wise enough to read their story. He seemed to feel that these objects were created for his special benefit and that there was nothing to fear from their presence. On the other hand if anything out of the ordinary appeared in the sky he was just as sure that it was also in some way related to his welfare and that it had some hidden purpose, if only he could discover it. In the Middle Ages almost every king was a firm believer in astrology and most of them employed a court astrologer whose duty it was to read the heavens and tell the king what was going to happen so that he could take measures to keep it from happening if he desired to do so.

On rare occasions a comet with its long train would appear in the sky, a meteor would shoot across the heavens, a new star would blaze out at a place where there had been no star before, or the sun or the moon would be eclipsed. Being ignorant of the fact that each of these phenomena is a direct result of certain natural laws, early peoples looked upon them as "signs" that had been sent by an angry God to warn his earthly subjects. Each of these "signs" had some hidden meaning. Surely something of the utmost importance was about to happen. Naturally under these

conditions the astrologer, who was supposed to be able to convey accurate information, was held in great reverence.

It seems to have been the general opinion of all early philosophers that an eclipse of the sun or moon was a sign of distress. Nature was sad because of some terrible calamity. According to an old Greek legend darkness covered the earth at the death of Hercules and several other mythological characters. The same thing is said to have happened immediately after the death of Romulus, the founder of Rome, and also of Julius Cæsar. There is also a Jewish legend to the effect that there was darkness over the face of the earth for three days after the Sacred Books were translated from Hebrew into Greek.

ECLIPSES HAVE CHANGED THE RESULTS OF MILITARY CAMPAIGNS

One of the earliest eclipses of which we have any record is mentioned in the Old Testament. Joel (II, 30-31) makes the Lord say, "I will shew wonders in heaven and earth, blood and fire and columns of smoke; the sun shall be turned into darkness and the moon into blood." The reddish color which the moon assumes during a total eclipse seems to have given rise to the expression "to turn the moon into blood." The prophet Amos (VIII, 9) says, "And it shall come to pass in that day, saith the Lord God, that I will cause the sun to go down at noon, and I will spread darkness over the earth in the clear day."

Astronomers tell us that a total eclipse of the sun occurred in southern Judea at noon in 1831 B. C. and another eclipse was visible in the same locality in 1824 B. C. Since both Joel and Amos were living at that time the two prophets seem to have written of a phenomenon which both had witnessed.

We find in history several examples of an eclipse of the sun exerting quite an influence on the result of a military campaign. We are told that on May 28, 548 B. C., an eclipse of the sun stopped a war between the Lydians and the Medes, although this eclipse had been predicted by the Greek astronomer, Thales. Upon one occasion the great Athenian general, Pericles, as he was about to sail with his fleet upon a great military expedition,

found himself stopped by an eclipse of the sun. The American Indians looked upon an eclipse as a warning sent by the Great Spirit. Upon several occasions Indian war parties were stopped by an eclipse of the sun and fled back to their villages in terror.

Many early peoples believed that when the moon was eclipsed it was fighting with a great dragon and they would come to its assistance by beating drums and other noise-making instruments in order to frighten the dragon and rescue the moon. Of course if they kept up the noise for two or three hours they were sure to be successful and, having once succeeded, they were apt to follow the same method of protecting the moon the next time it needed their assistance. Even at the present time this method of driving the dragon away from the moon is employed by several ignorant and savage races.

EARLY SCIENTISTS COULD PREDICT ECLIPSES

Although we are amused at the ideas of ignorant people with reference to eclipses of the sun and of the moon, we must not lose sight of the fact that scientific men of very early times noticed that eclipses recurred at regular intervals. We have several well authenticated examples of instances where the leading thinkers of the day understood the cause of eclipses and were able to predict them. The Chinese claim to have been predicting eclipses for almost 4,000 years. In fact, an eclipse of the sun which occurred in China in the year 2169 B. C. is said to have cost two court astronomers their lives because they made some error in their calculations and the eclipse did not arrive on time.

At least 3,500 years ago the Chaldeans discovered the lunar cycle of 223 lunar months, known as the Saros, and began to make a careful record of all observed eclipses. Several of the Greek philosophers seem to have had a clear understanding of the cause of eclipses and they frequently predicted them. However, their data with reference to the sun, moon and earth were so inaccurate that most of the eclipses did not arrive at the proper time.

Columbus used his knowledge of eclipses to free himself and his companions from the American Indians, who held them pris-

oners and had reduced them almost to starvation. Although Columbus was in no sense either a mathematician or an astronomer, he happened to remember that a lunar eclipse was due to occur on March 1, 1504, and he threatened to cause the moon to disappear if the natives did not release him and give him something to eat. The Indians paid little attention at first but when the shadow of the earth began to blot out the moon they brought him plenty of food and worshipped him as a god.

Of course very little progress was made in developing an accurate method for predicting eclipses until man learned more about his universe. Every new discovery in astronomy has contributed to the accuracy of these results. We can now determine very accurately for years in advance the motions of the sun, the earth and the moon, so that when the astronomers of the twentieth century tell us that an eclipse will be visible at a certain time and in a certain place we may be sure that it will arrive as predicted.

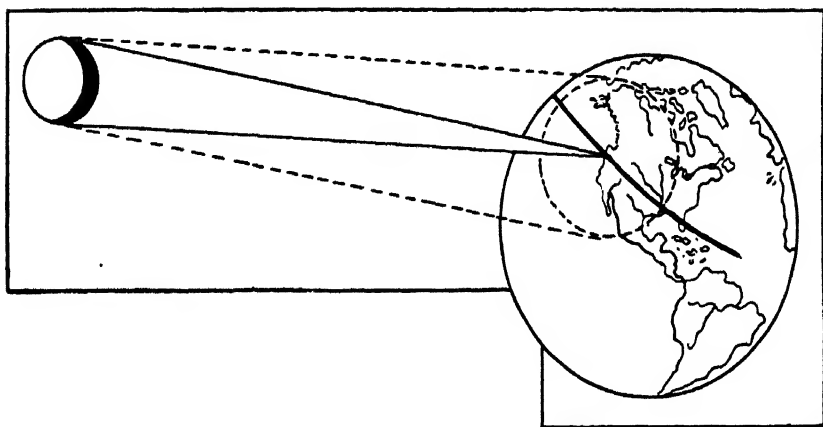
WRITERS SOMETIMES MAKE HEAVENLY BODIES MISBEHAVE

We are sometimes amused at the efforts of some of the leading thinkers of early times to explain the relation between the heavenly bodies and to interpret celestial events when they occur. These crude and erroneous ideas, however, are not confined to that period in our history when the human race was suffering from ignorance and superstition and astrologers were so highly respected and so well paid that even Kepler found it to his advantage to add to his income by devoting his spare time to this so-called science, for even in the twentieth century our newspaper reporters sometimes have very curious ideas with reference to celestial events.

On the sixth of June, 1918, the shadow of the moon swept across the United States from Oregon to Florida and caused a total eclipse of the sun which was seen by many people along the shadow-path. For several days prior to the eclipse the newspapers were filled with eclipse stories of one kind or another, but the most interesting of these appeared in a Wisconsin paper and

read as follows: "Residents of Wisconsin will have an opportunity to witness a total eclipse of the sun on the afternoon of June 8. The eclipse may be seen from 1:30 until sundown and according to authorities the moon and sun, one on each side of the earth, will pass each other some time during that period."

One of the reporters on the *Chicago Tribune*, who was familiar with the solar system and had evidently been keeping himself posted on astronomical events, saw the absurdity of this state-



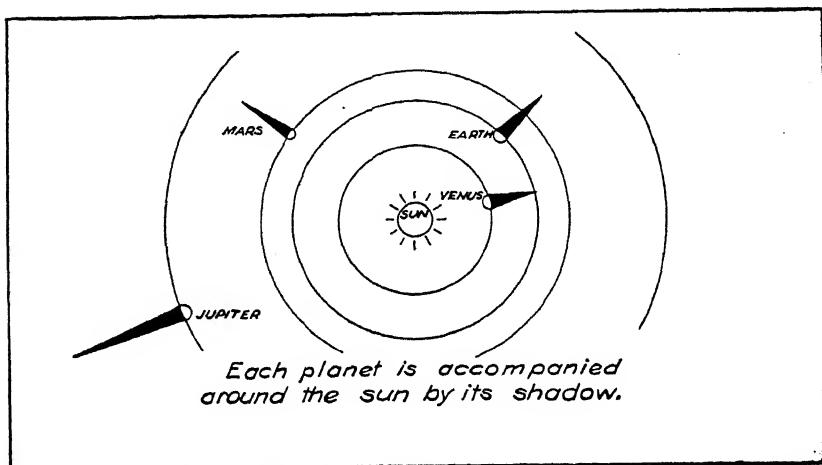
Only those living in the narrow shadow-path extending from Oregon to Florida saw the total eclipse of June 6, 1918.

ment and on the sixth of June the *Tribune* quoted the above paragraph with the following comment: "Barring the facts that the total eclipse will not be visible in Wisconsin, that it lasts only two minutes or less, and that the earth is not between the sun and the moon, the information purveyed by the —— paper is almost painfully accurate."

Immediately after another total eclipse of the sun a daily paper of wide circulation appeared with the following headline, "The Moon Casts Its Shadow on the Sun." The absurdity of this statement is obvious. The sun is the source of light. Then how could a shadow be thrown on it? As a matter of fact the sun was invisible because the moon passed over it. The moon's shadow was on the earth and not on the sun.

THE EARTH IS ALWAYS ACCOMPANIED BY ITS SHADOW

The sun's rays are radiated in every direction throughout space. Some of these are intercepted by the planets and their moons and give off light and heat. Thus every member of the sun's family excludes the sunlight from a small part of space, forming a shadow which accompanies it on its trip around the sun and always points away from the source of light. In this



shadow there is no sunlight except a small amount that may be refracted into it by the atmosphere of the planet.

When we see a shadow on the ground we usually think of it as something flat like a leaf. As a matter of fact a shadow is a portion of space—three dimensions—from which the light is excluded by an intervening object. Of course an object in the shadow of a house or a tree is not invisible as would be the case if it were behind the house or tree, because the earth has an atmosphere which bends the rays of the sun into the shadow. However, on the moon, or on any other heavenly body with no atmosphere, the shadows are absolutely dark. Since the sun is very much larger than any of the planets or moons their shadows will be cones; that is, they will come to a point.

As the earth moves around the sun year after year it is accompanied by its shadow which of course always remains on the

side of the earth away from the sun. The base of the shadow moves through space at the rate of eighteen and a half miles per second but most of us are not aware of its existence. As we drive along our highways at night the lights on our automobiles throw shadows of intervening objects across the landscape which can be seen moving along the ground, but the earth's shadow is not noticed except when it passes over some celestial body.

The ancients thought that the light of the sun was put out every evening and rekindled every morning. In this way they were able to account for the alternation of light and darkness. We know that darkness is due to the fact that we are in the shadow of the earth and that the succession of night and day is caused by the rotation of the earth which carries us into the shadow every evening and brings us out again every morning.

THE EARTH'S SHADOW IS 857,000 MILES LONG

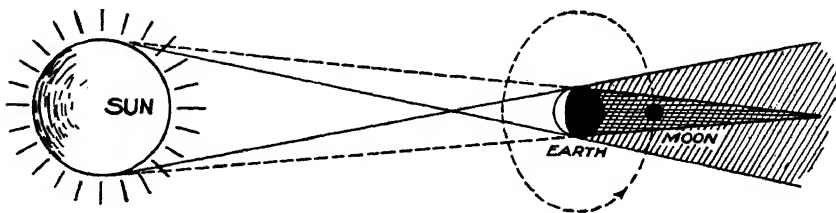
When we recall the fact that the shadow of the earth is not something flat which covers the earth like a layer of snow, but that it is a cone whose base is the earth and whose vortex is somewhere out in space in the direction opposite that of the sun, we naturally wonder about its length—how far does it reach? We know that when night comes it is just as dark upstairs as it is downstairs. If we climb to the roofs of our highest buildings we find darkness there. When the birds of the air fly at night they are invisible no matter how high they may be. Aviators may destroy a city by dropping deadly bombs from purring airplanes while they remain invisible, protected by the shadow of the earth. No matter how high they may go they are still in the shadow.

The answer to our question is furnished by the astronomers who tell us that the average length of the earth's shadow is 857 thousand miles and that its length varies about 14 thousand miles on account of the fact that the earth is not always at the same distance from the sun. The shadow is shortest in January when we are closest to the sun and longest in July when we are farthest away.

As the moon makes its monthly circuit around the earth at a distance of about 238 thousand miles, which is less than the

length of the earth's shadow, it may happen that it will go into the shadow and be eclipsed. This seldom happens more than twice a year.

Since the moon is moving eastward around the earth its eastern limb will first come in contact with the shadow and, if it happens to pass near enough to the center of the shadow so that



The earth's shadow extends 857,000 miles out into space.

its entire disk is buried in it, we then have a total eclipse of the moon. The moon does not completely disappear during a total eclipse because the refraction of the atmosphere of the earth deflects the sunlight around the earth into the shadow and causes the moon to shine with a reddish or copper-colored light. If the earth were suddenly robbed of its atmosphere during a total lunar eclipse the moon would disappear immediately.

A LUNAR ECLIPSE CAN OCCUR ONLY AT FULL MOON

It is obvious that the moon can be in the shadow of the earth only when it is on the opposite side of the earth from the sun so that every lunar eclipse must occur at the time of full moon. How amusing is the following statement which once appeared in a daily newspaper at the end of a paragraph describing a recent eclipse of the moon, "This eclipse was especially beautiful since it occurred at the time of full moon." As a matter of fact it could not have occurred at any other time.

Since the shadow of the earth is a cone, the diameter of any cross section will depend upon its distance from the earth. The maximum diameter at the place where the moon crosses it is 5700 miles, which is about two and two-thirds times the diameter of the moon. Since the moon moves a distance equal to its own

diameter every hour it follows that an eclipse of the moon when central may continue total for almost two hours.

If the moon goes into the shadow but passes so far above or below the center that only a portion of its disk is hidden from view, we then have a partial eclipse of the moon. Of course the orbits of the moon and the earth are so related that the moon generally passes above or below the shadow without touching it, otherwise we would have a lunar eclipse every month.

There is nothing mysterious about an eclipse of the moon. No heavenly body intervenes between us and the moon at the time of an eclipse. The light which reveals its surface to us has merely been cut off. If the moon could shine by its own light it would never be eclipsed. The dates of lunar eclipses are determined several years in advance and published for the information of all concerned.

There is an old legend to the effect that the Man in the Moon keeps the Woman in the Moon in chains most of the time because she is always disturbing him by her housecleaning. However, at more or less regular intervals he is forced to release her and she then devotes her attention to this project with so much energy that the resulting cloud of dust hides the moon from the eyes of mortal men until she has finished her task.

THE MOON'S SHADOW IS 232,000 MILES LONG

The earth has a shadow which accompanies it on its journey around the sun and which sometimes strikes the moon and causes that body to be eclipsed. The moon is also accompanied by a shadow which sometimes falls upon the earth and causes an eclipse of the sun. It is obvious that a person standing in the shadow of the moon would find that the moon was between him and the source of light, the sun.

It may be well to call attention to the mechanical difference between an eclipse of the moon and an eclipse of the sun. During a solar eclipse we are unable to see the sun because we cannot see through the moon which is between us and the sun; but at the time of a lunar eclipse the moon becomes invisible simply because there is no light shining on it.

The sun and moon appear to be about the same size. This is due to the fact that although the sun is about 400 times as large as the moon it is about 400 times as far away. Consequently, when the moon gets between us and the sun we would expect its shadow to be just long enough to reach the earth. However, the mathematicians tell us that the length of the moon's shadow varies from 228,000 miles to 236,000 miles, the average length being 232,000 miles, so that on the average it is not quite long enough to cover the 238,000 miles which separate us from the moon. Even when we do happen to be close enough to the moon for the shadow to reach us its cross section at the earth is very small, reaching a maximum of 167 miles only on very rare occasions.

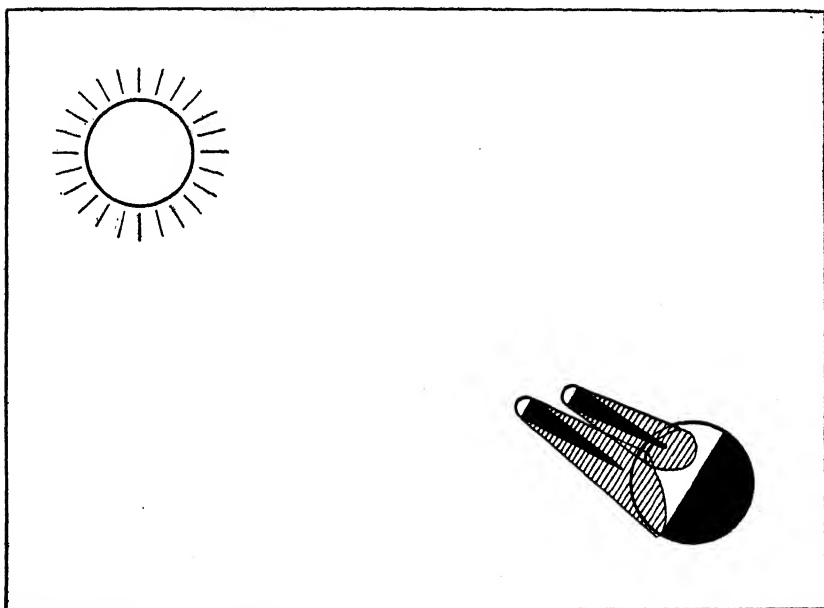
Nature has so arranged the orbit of the moon that its distance from the earth varies from 218,000 to 248,000 miles, so that its shadow sometimes reaches the earth and sometimes does not. Thus we have the pleasure of witnessing solar eclipses of two different types. When the shadow strikes the earth those of us who happen to be in the shadow see a total solar eclipse. The moon usually appears just large enough to cover the face of the sun and, since it is moving very rapidly, it cannot hide the sun very long so that a solar eclipse seldom remains total longer than two or three minutes.

SOLAR ECLIPSES MAY BE TOTAL, ANNULAR OR PARTIAL

When the moon comes between the earth and the sun its shadow sometimes reaches the earth and sometimes does not, so that we have solar eclipses of two different types. When the shadow is long enough to touch the earth we have a total eclipse but when the shadow fails to reach us the moon will not quite cover up the face of the sun and a ring of light will be left around the edge of the moon. An eclipse of this nature which is much more frequent than a total eclipse is known as an annular or ring-shaped eclipse. Because of the curvature of the earth's surface some parts of the earth are several thousand miles closer to the moon than others. Thus as the moon's shadow sweeps

across the earth it may touch the earth part of the time and then lift itself above its surface. Consequently a solar eclipse may be total along a part of the shadow path and annular along another part.

The width of the moon's shadow at the place where it strikes the earth is never more than 167 miles and is generally much less. Every one within the narrow strip where this shadow



The moon's shadow is not always long enough to reach the earth.

traverses the surface of the earth will see the moon pass across the face of the sun. Observers within 2000 miles on either side of this strip will see a partial eclipse of the sun. That is, as the moon passes between them and the sun its center will pass to one side of the center of the sun leaving one limb of the sun visible all of the time.

Those who happen to be near the narrow strip will see the eclipse almost total, while those 2000 miles away will scarcely see any of the sun's disk covered by the moon. For those who live more than 2000 miles from this strip the sun will continue to shine just as if nothing were happening. In other words, it is possible for an eclipse of the sun to be total for some observers and partial for others at the same instant, but invisible to those

not so favorably situated at the time. This is not true of lunar eclipses. If the moon is completely in the shadow of the earth then everyone on the earth who can see the moon at all will see it immersed in the shadow.

A SOLAR ECLIPSE LASTS ONLY A FEW MINUTES.

In order that we may thoroughly understand the mechanics of solar and lunar eclipses we must keep in mind the fact that the earth is revolving around the sun and the moon is moving around the earth. At more or less regular intervals the moving shadow of the moon sweeps across our flying world and some of us see an eclipse of the sun.

How long may the sun remain in total eclipse under the most favorable circumstances? Let us see if we can arrange the positions of the sun, the moon, the earth and the observer in such a way as to obtain the maximum period of totality. In order that this hypothetical eclipse may be total for the longest possible time the shadow path across the earth must be as wide as nature can ever allow it to get. But the width of the moon's shadow where it strikes the earth depends upon the distance from the sun to the earth and upon the distance from the moon to the earth, neither of which is constant. The maximum width will be obtained when the sun is farthest from us and the moon is closest to us.

If the earth were not rotating the moon's shadow would pass an observer at the rate of 2100 miles an hour, but the rotation of the earth carries the observer with a speed which varies from zero at the poles to 1040 miles an hour at the equator in the same general direction in which the moon's shadow is moving, so that the actual duration of a solar eclipse will vary with the latitude. Total eclipses last longest on the equator where the rotational speed of the earth reduces the apparent velocity of the shadow to only 1060 miles an hour. If the earth should rotate twice as fast a solar eclipse would remain total for hours.

There are certain other factors that must be taken into consideration when nature produces for us this hypothetical eclipse

of greatest possible duration. But when it does come our observer will be on the earth's equator and it will be a July eclipse, for we are farthest from the sun during that month. According to Miss Isabel Lewis of the U. S. Naval Observatory the period of totality will be seven minutes and thirty-one seconds, and this is the greatest possible duration for a total solar eclipse.

A TOTAL SOLAR ECLIPSE IS A GREAT ASTRONOMICAL SHOW

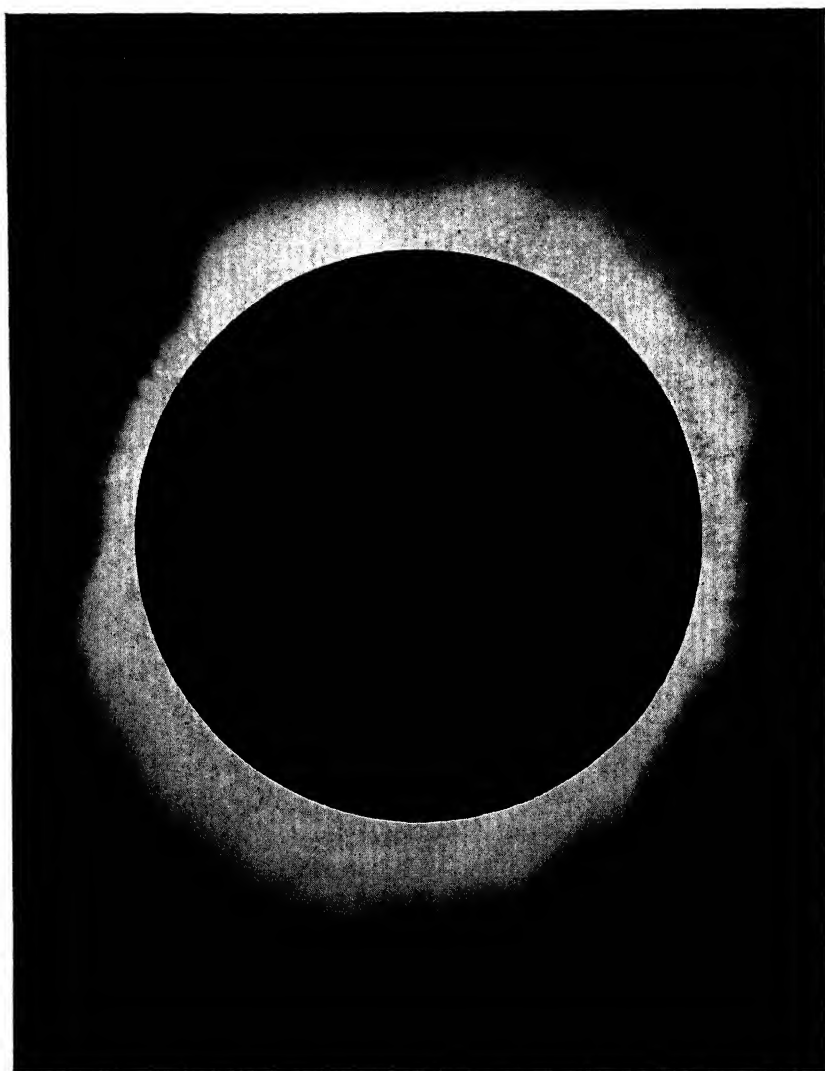
The moon attracts very little attention as it faithfully obeys the Law of Gravitation and moves quietly around the earth. We sometimes note that it has changed its phase but we do not become excited because usually nothing happens. Only when the moon is new is there any possibility of a solar eclipse and as a rule it assumes this phase when far enough from the ecliptic to enable us to avoid a collision with its shadow.

When a total eclipse of the sun does occur we witness the greatest astronomical show ever exhibited before the human race. The three actors—the sun, the earth and the moon—play their respective roles silently in the death-like stillness of space. No sensational pictures or exaggerated statements on screaming posters announce from high billboards or farmers' barns the time and place of the nearest performance, only the modest announcements of our astronomers appearing in small type in our scientific journals. On the day of the performance thousands of curious-minded people, and perhaps a hundred scientific men, occupy positions along the predicted shadow path from which they may witness the approaching spectacle.

At the appointed hour the moon moves slowly and majestically across the face of the sun and the light of our celestial lamp is gradually extinguished. From a well selected position of observation from which many miles of the earth's surface are visible, one may actually see the gigantic shadow of the moon as it rushes across the earth with a speed of more than a thousand miles an hour and turns day into night so that the show may be visible against the dark background of the sky. The air suddenly becomes cool, the chickens go to roost as if the day were

ended, the the bull frogs on near-by streams start their usual nocturnal music.

The corona of the sun, hidden from mortal view since the last



The total solar eclipse of May 28, 1900.—Yerkes Observatory.

total eclipse, flashes out suddenly; the planets whose feeble light has been lost in the brilliancy of the sun's rays blaze out in their appointed places and the entire dome of the sky is filled with stars which seize this opportunity to wink at us in the daytime

across the immeasurable depths of space. The celestial show is on. No blare of trumpets announces the different acts and no brass band deafens the audience, the only accompaniment is the inaudible "music of the spheres."

SOLAR ECLIPSES ARE PREDICTED YEARS IN ADVANCE

Nature has so constructed the orbits of the earth and the moon that eclipses occur at regular intervals of eighteen years and eleven and one-third days. That is, if an eclipse occurs today there will be another one at the end of this period. Of course there will be many others before that one—usually about 71 solar eclipses and a score or more of the moon—but there is sure to be one then. This period, which was known to the ancient Chaldeans, is called the Saros.

For obvious reasons the calculation of a solar eclipse is more difficult than an eclipse of the moon. These calculations, however, are made several years in advance and are published for the information of all concerned. The astronomer, Oppolzer, published in 1887 a book explaining the 13,200 eclipses—8,000 solar and 5200 lunar—occurring between 1207 B.C. and 2162 A.D. This book contains maps showing the paths of all total or annular solar eclipses. A stupendous work, indeed!

Perhaps you have often wondered how the astronomers can be sure of the accuracy of their measurements of the distances to the sun and to the moon, the diameters of the sun, of the moon and of the earth, the velocities of the moon and of the earth, and some of the other facts about the movements of the heavenly bodies. In the calculation of an eclipse the astronomer makes use of all of these figures and if any one of them should be inaccurate the result would certainly be incorrect. Now it so happens that every eclipse occurs at the exact time, and is visible in the exact place, predicted by these scientists. Who could ask for a more convincing proof of the accuracy of these astronomical facts?

You may perhaps be under the impression that eclipses of the sun must occur between 6 A.M. and 6 P.M. and eclipses of the

moon between 6 P.M. and 6 A.M. This certainly sounds reasonable but people in the polar regions may see a solar eclipse at midnight if the moon's shadow strikes them at the season of the year when the midnight sun is visible. This actually happened in the case of the annular eclipse of October 21, 1930. These same people may also see a lunar eclipse at noon if it happens to occur during that season of the year when the sun is below the horizon.

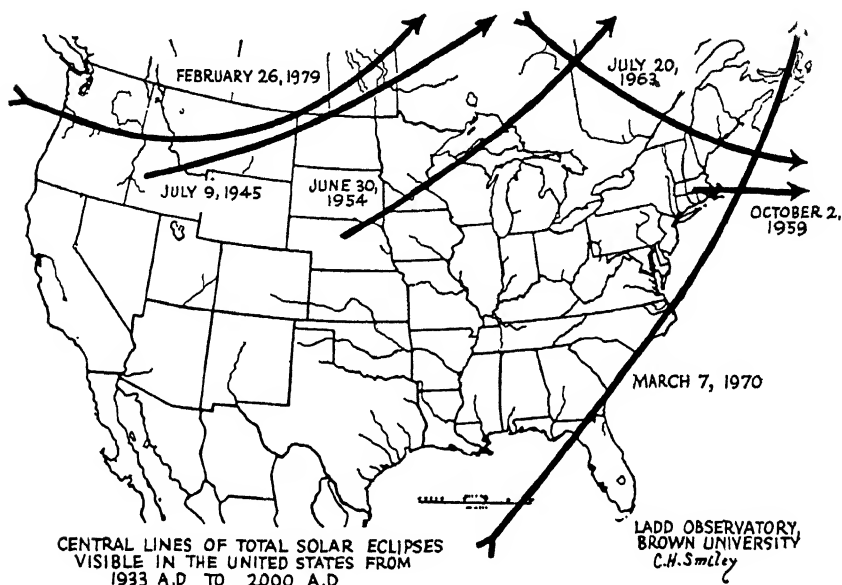
THE NEXT SOLAR ECLIPSE OCCURS IN 1945

The total solar eclipse of 1932 was seen by a large number of people and that part of New England that was to be traversed by the shadow path fairly bristled with telescopes, cameras, etc., on the morning of the thirty-first of August. Along this imaginary line were to be found scientific men from astronomical observatories all over the world, and also thousands of people who were attracted to the spot, not by their scientific zeal but merely because they wanted to see the astronomical show. This great celestial spectacle aroused the interest of so many thousands of our people that many are asking when we will be able to see another total eclipse of the sun.

We are advised by Dr. Charles H. Smiley that the moon's shadow will strike the United States only six more times during the twentieth century so that those who would like to see more than six total eclipses of the sun before the end of the century must travel beyond the limit of continental United States. According to Dr. Smiley, the first three of these eclipses—July 9, 1945; June 30, 1954; October 2, 1959—will occur at, or near, sunrise and will be of very little value from a scientific point of view and the eclipse of July 20, 1963, will be visible in Maine at 5:40 P.M., daylight saving time, with the sun only twenty-seven degrees above the western horizon. The eclipse of March 7, 1970, will last about 200 seconds with the sun high in the sky and on February 26, 1979, a total eclipse will occur in the middle of the afternoon and will last about 160 seconds.

We will miss three total eclipses during the remainder of the twentieth century because they occur while the moon is too far

from the earth to completely cover the face of the sun. The first of these annular eclipses is scheduled for September 1, 1951, and will be visible in the southeastern part of the United States. On May 30, 1984, a second annular eclipse will occur with the shadow sweeping across the southeastern part of the United States. The third annular eclipse will occur on May 10, 1994, and will be seen from the southwestern part of the United States to New England.



The total solar eclipse visible in the United States during the remainder of the twentieth century. Courtesy, C. H. Smiley, Brown University.

THE SUN IS ECLIPSED BY NEW MOON; THE MOON IS ECLIPSED WHEN FULL

It is obvious that an eclipse of the sun can occur only at new moon when the moon is between the earth and the sun; and that the moon can be eclipsed only at full moon when the earth shuts out the sunlight from that part of space occupied by the moon.

Were it not for the fact that the orbit of the moon does not quite coincide with the plane in which the earth is moving there

would be a solar eclipse at every new moon and a lunar eclipse at every full moon. These two orbits cross at an angle of about five degrees so that when the moon is new or full it is usually far enough out of line with the earth and the sun to avoid a lunar or solar eclipse. The two points of intersection are called the nodes and it is only when the moon is near one of the nodes of its orbit at the time of new or full moon that an eclipse can occur.

In every calendar year new moon will occur at least twice, and sometimes three, four or even five times, with the moon so close to one of the nodes of its orbit that its shadow will sweep across the earth, causing an eclipse of the sun. On the other hand a calendar year may pass without a single full moon occurring near enough to a node to result in a lunar eclipse. However, we usually have at least one lunar eclipse every year and a single calendar year may contain as many as three.

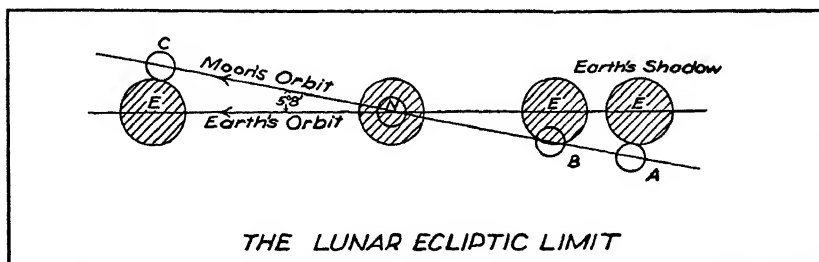
Since neither the moon nor the sun can be eclipsed except when the moon is near one of its nodes, eclipses always occur at opposite seasons of the year. Thus, if the moon is eclipsed at the time of the April full moon it cannot be eclipsed again until September or October. These two seasons are known as the "eclipse seasons" of the year. This was obviously true of the five eclipses of 1931 which occurred on April 2, April 17, September 12, September 26 and October 11. For reasons which we will not attempt to explain the eclipse year is somewhat shorter than the calendar year so that the eclipse seasons move steadily backward through the year and it is possible to have three eclipse seasons in a single year if the first eclipse occurs early in January.

THERE MAY BE AS MANY AS SEVEN ECLIPSES IN A SINGLE YEAR

If full moon occurs while the moon is close to one of the nodes of its orbit it is sure to be eclipsed. The moon must "run the gauntlet" through this danger zone at least twice, and sometimes three times, in every calendar year. If full moon occurs just before the moon goes into the danger zone it may

pass entirely through the zone before the next full moon and "get by" without being eclipsed. This may happen at several consecutive node passages so that it is possible to have a calendar year without a single lunar eclipse, but we usually have one or two and sometimes three.

The moon can eclipse the sun only when new moon occurs near one of its nodes. These danger zones include the two men-



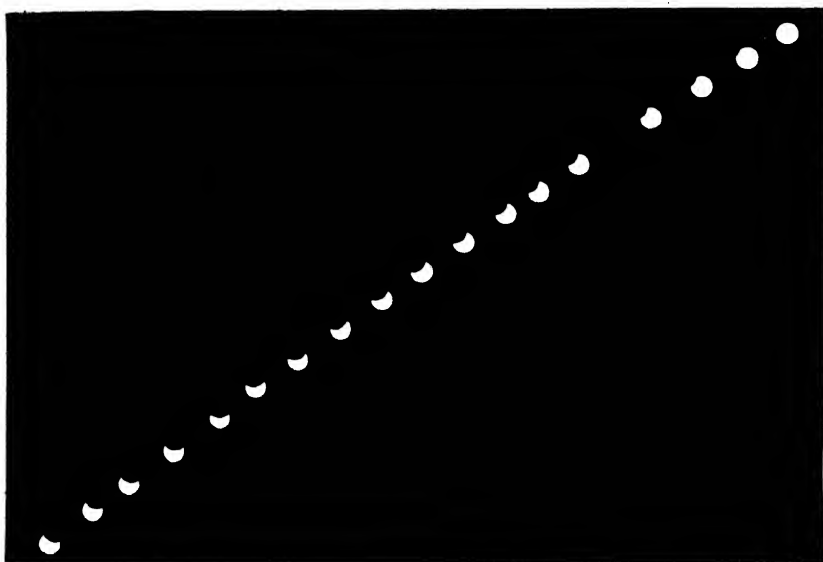
The moon travels from A to C in about twenty-five days, so all lunar eclipses occur within twelve and one-half days of the time of the passage of the moon through one of the nodes of its orbit.

tioned above but are so much longer that the moon requires more than a month to pass through either of them. Consequently, at the new moon nearest to each node passage observers somewhere on the earth can see either a total or an annual eclipse of the sun.

If the moon is "new" immediately after it enters the danger zone it may become "new" again before it gets out, so that the sun may sometimes be eclipsed at two consecutive new moons. This happened in 1935, the sun being eclipsed at new moon on January 5 and at the next new moon, February 3. Since these double eclipses may occur twice a year there may be four solar eclipses per year. However, there may be thirteen new moons in a calendar year, so that it is possible to have as many as five solar eclipses in a single year if the first one occurs near the first of January. When solar eclipses occur at consecutive new moons there must be a lunar eclipse at the intervening full moon, so that a year with five solar eclipses must have two lunar eclipses. Consequently, there may be as many as seven eclipses in a single calendar year. The present year (1935) is one of these remarkable years with seven eclipses.

Although the greatest possible number of eclipses per year

is seven, there may be four of the sun and three of the moon as well as five of the sun and two of the moon. This happened in 1917. The most usual number of eclipses per year is four, two of the moon and two of the sun, and the least possible number is two, both of the sun.



Partial eclipse of the sun, February 3, 1935, as photographed in Little Rock, Arkansas, by D. D. Rayfield of the *Arkansas Gazette*.

THERE ARE MORE SOLAR THAN LUNAR ECLIPSES

If the entire surface of the earth be taken into account there are more eclipses of the sun than of the moon. That is, the moon cuts off a part, or all, of the sunlight from observers on some part of the earth much more often than it goes into the shadow of the earth. The ratio is approximately three to two. However, if the observer remains at any given place on the earth, the result is entirely different. The reason for this will be perfectly obvious after a little reflection. Let us remember that the full moon is visible from half the surface of the earth so that everyone on one side of the earth will see it go into the shadow. Because of the rapid rotation of the earth many other observers, who did not see it go in, will see it come out. Thus every lunar

eclipse is visible from more than half the surface of the earth, while a solar eclipse may be seen from a very limited area.

On the other hand, a solar eclipse is total, or annular, only for those who live in a narrow strip, which is usually less than 150 miles wide, and only a few thousand miles long. Suppose some inhabitant of Mars should reach his arm across the intervening space and, with a brush 150 miles wide, paint a streak at random across the face of the earth as it spins rapidly on its axis. What is the probability that your house would be painted? And you would not see the eclipse as total, or annular, unless your house was painted. In fact, unless you were close enough to smell the paint there would be no possibility of your seeing even a partial eclipse. That is, you could not tell by looking at the sun that anything was happening. An observer at a given place on the earth will see a total eclipse of the sun on the average about once in 400 years.

If an eclipse of the sun is visible both in Minnesota and in Connecticut the observer in Minnesota will see it first because the moon's shadow is moving toward the east. If a lunar eclipse is visible in both of these states the observer in Minnesota will see it at the same time as the observer in Connecticut. In fact, a lunar eclipse occurs at the same instant for every observer who is so situated that he can see it.

ECLIPSES VISIBLE FROM OTHER WORLDS

While we are enjoying the eclipses of the sun and of the moon which nature produces at intervals for our amusement we cannot help but wonder whether we would ever witness these celestial shows if we lived on the moon. From the back side of the moon the earth would never be visible and consequently eclipses of the sun and of the earth would be unknown. But let us suppose that we live on our side of the moon. Then when the moon goes into the shadow of the earth we would see an eclipse of the sun for the earth would be between us and the sun. The black disk of the earth, apparently fourteen times as large as the sun, would cut off our supply of light and heat for several hours and leave us in utter darkness and intense cold, because

of the absence of atmosphere. Suppose, on the other hand, that the moon's shadow traverses the earth. Then we would see an eclipse of a part of the earth. That is, we would see a small black dot pass across the face of the earth at the enormous speed of more than 1000 miles per hour.

All that has been said with reference to eclipses applies not only to us but also to the inhabitants of other worlds. However, nature seems to have been somewhat partial to the earth when arranging the dimensions of the solar system, for although some other planets have many more moons than we have, their arrangement seems to be such that total eclipses of the sun are visible only from the earth. If the sun were somewhat larger, or the moon somewhat smaller, our celestial lamp would never be extinguished; if the sun were a little nearer the earth, or the moon a little farther away no inhabitant of the earth would ever witness a total eclipse of the sun.

Although inhabitants of other worlds are apparently denied the pleasure of witnessing a total eclipse of the sun, it is rather unfortunate for those of us who are interested in eclipses of the moon that we do not live on Jupiter or Saturn. Each of these planets has nine moons which move around their primary worlds so rapidly that lunar eclipses occur every day or so and undoubtedly furnish much entertainment for those who are interested in celestial events of this kind.

IN EARLY DAYS COMETS WERE SIGNS OF WRATH OF HEAVEN

Eclipses of the sun and the moon were of course not understood by early peoples and were looked upon as "signs" that had been sent from heaven for some definite purpose. There were other so-called irregular parts of the universe which attracted even more attention than eclipses. On very rare occasions a bright comet with a tail several degrees in length would appear in the sky as a sign of the wrath of heaven. Comets always foretold the dethronement of kings and the dissolution of empires and were usually associated with some critical period in history. This was very easy to do because it was natural to recall the comet that appeared near the death of some prominent person

and to forget all about the other comets which apparently came at the wrong time.

The Romans were a nation of builders and paid very little attention to "signs" in the sky, yet many believed that the comet of 44 B.C. was sent to convey the soul of Julius Cæsar to its final resting place. The death of the Emperor Nero is said to have been announced by the appearance of a comet. In 69 A.D. while Jerusalem was being besieged by the Roman legions under Titus a great comet appeared and all agreed that it was now time for the fulfillment of the prophecy that the temple should be destroyed and not one stone left upon another.

A great comet appeared in 1066 at the time of the Norman Conquest and another bright one in 1456 is said to have attracted so much attention that in every Christian church in Europe a special prayer was added for protection from the devil, the Turk and the comet. Other bright comets appeared in 1566, 1572 and 1577. It is interesting to note that about this time, while some people were preaching to their ignorant and superstitious followers that comets were the souls of mortals wandering in space, others that comets were sent to foretell the approaching end of the world, others that they were the work of the devil, and still others that comets were the sins of mortals which, ascending to heaven and coming to the attention of God, were set on fire by his wrath, the great Danish astronomer Tycho quietly continued his observations and announced that the comet of 1577 was beyond the moon. In other words, that it was not in our atmosphere at all.

COMETS CAUSED PANICS AMONG UNEDUCATED PEOPLE

The feeling of terror which spread over the world at the sudden appearance of a comet was not confined to ancient times. Shakespeare and Milton, writing at the close of the sixteenth and near the middle of the seventeenth centuries, frequently referred to the effect of comets on the lives of mortal men. Of course it is possible that they were merely attempting to ridicule the common superstitions of their day, but no one has yet produced any evidence which would lead us to believe that their

own ideas about comets differed in any way from those expressed in their works.

The eruption of Mount Vesuvius in 1618 was said to have been foretold by the brilliant comet of that year. In 1680 a bright comet appeared which created so much excitement in Germany that a medal was struck and widely distributed to restore quiet. On one side was a picture of the comet and on the other the words, "Only trust! God will make things turn to good." Many people, believing that this comet had come to announce the end of the world, made their wills and left their money to the monks who, in accepting it, proved themselves better students of astronomy than their would-be benefactors. Newton later, using data furnished by this very comet, proved that all comets are moving around the sun under the influence of certain definite mathematical laws.

Edmund Halley, to whom we are indebted for bringing the results of Newton's researches to the attention of the scientific world, became interested in the great comet of 1682 and worked out the details of its orbit. He found that this comet had been making its appearance every seventy-five or seventy-six years and on at least two different visits (in 1066 and in 1456) had been associated with important historical events. He confidently predicted that it would be visible again in 1758, in 1835, and in 1910. In each case his prediction was confirmed. When this comet was picked up on Christmas Eve, 1758, it was realized that Newton's law of universal gravitation had been put to its first test and had won. Before the time of its last visit to the earth its orbit had become so well known that the exact time of its return was predicted with an error of only eleven days, although the comet had been invisible for more than seventy years.

EDUCATED PEOPLE FOR MANY CENTURIES HAVE UNDERSTOOD BEHAVIOR OF COMETS

Even after Newton had published his mathematical results and had shown that comets are members of the solar system, which are moving around the sun like the earth and the other planets, ignorant and superstitious people were still terrified by

the appearance of one of these ghosts of the skies. Even as late as the last half of the eighteenth century we find people writing and preaching that the flood of Noah was caused by a comet's tail striking the earth and that the great comet of 1665 caused the Plague of London, although it seems to have had no effect on any other city.

As man became better acquainted with comets they gradually lost their terrors. However, the old superstitious dread of comets held on for a long time. It is said that when Halley's comet paid us its last visit in 1910 a certain colored physician in a Southern city made himself independently rich by prescribing "comet pills" for his patients, which they took every hour until the comet passed by. Perhaps some of them took a pill every half-hour in order to be on the safe side.

While we of the twentieth century are amused at the superstitions of the Middle Ages we must not forget that the true theory of comets is by no means modern. The Chaldeans, to whom we are indebted for the Zodiac, believed that comets were harmless just as fish in the sea and that they revolved about the sun. The Greek philosopher Aristotle refused to believe that comets had a supernatural origin and taught that they were merely exhalations from the earth. The Roman writer, Seneca, said that comets were beyond the moon and were moving according to certain definite laws.

The old dread of comets is gradually passing away. We now know that comets are not "signs" that have been hung up in the sky by an angry god in order to warn mortals, but that they are regular members of the solar system. It is true that they do not resemble in appearance the planets, or the moons, or even the stars, but every comet as far as can now be determined is moving around the sun in a perfectly definite orbit just as the planets do and will come back to the vicinity of the earth at regular intervals—perhaps in some cases only after several centuries have elapsed.

COMETS ARE VERY DIFFERENT FROM PLANETS

Comets are very different from planets both in general appearance and also in many other respects. Planets are spherical



Morehouse's Comet, November 16, 1908.—Yerkes Observatory.

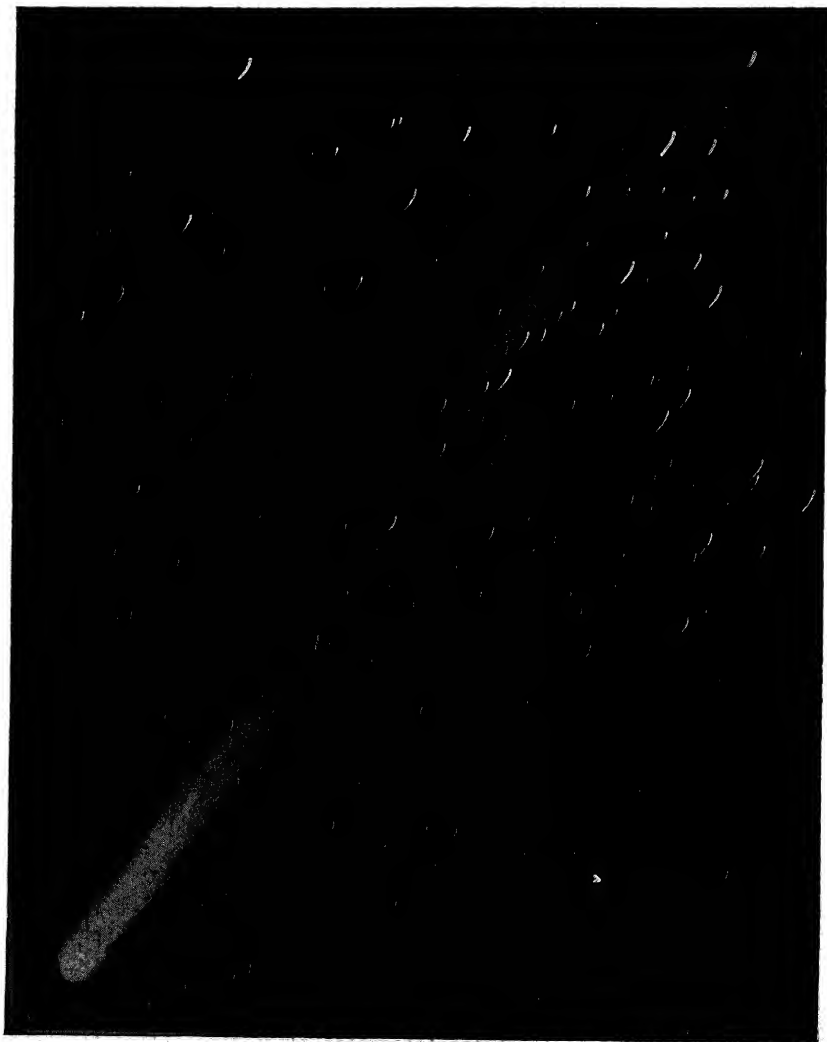
in shape; they are bodies of considerable density, in most cases greater than that of the earth. Comets are irregular in appearance; they usually have large nebulous heads from which tails extend several million miles into space. They frequently change their shape within a period of a few days to such an extent that they can hardly be recognized. They have very little density and we have no weighing machinery delicate enough to determine their weight. They are called comets from a Greek word which means "long haired." This word, however, should not be taken literally for, although bright comets do have tails, the modern photographic plate reveals many faint comets that are entirely devoid of tails.

When a large comet comes close to the earth it is a magnificent object and may even be brighter than Venus and visible in the day time. We have records of about 900 comets that have visited the vicinity of the earth and we may expect this number to increase very rapidly for the modern telescope now reveals from five to ten in a single year. Since it is possible for us to see only those that happen to pass very close to the earth the total number going around the sun must be enormous. Comets often appear quite unexpectedly and are very easily "picked up" by an observer with the proper instruments. It is said that an American once offered a prize of \$200 for every new comet to be discovered and a prominent astronomer paid off the mortgage on his home by finding nineteen of them within a few years.

Comets are moving very swiftly so that observers on our flying world are not able to keep them under observation for any great length of time. The average comet is usually visible for just a few months, although several very large ones have been followed by our telescopes for more than one year. On the other hand, it frequently happens that a comet is photographed during a total eclipse of the sun which is not visible either before or after the few minutes of darkness. After a comet sweeps around the sun it then goes out into space from whence it came to return to the vicinity of the earth at its appointed time.

COMETS' TAILS ARE THE RESULT OF LIGHT PRESSURE

Although the nucleus, or head, of a comet varies from 30,000 to 150,000 miles in diameter, the tail is by far the most imposing feature. Its length varies from five million to 200 million miles. In fact, on several occasions our part of the universe



Brooks' Comet, October 23, 1911.—Yerkes Observatory.

has been visited by comets with tails long enough to span that enormous distance which separates the earth from the sun.

The tail of a comet always points in the general direction away from the sun, the amount of curvature depending partly upon its velocity and partly upon the weight of the material of which it is composed. Most people agree that the material in a comet's tail was originally pulled out of the head of the comet by the sun. As this light material moves toward the sun under the attraction of gravitation it finally reaches a point where the repulsive power of sunlight overcomes the force of gravitation and it is driven back away from the sun. This explains why comets' tails always point away from the sun. There is no reason to suppose that the material which is pulled out of the head of a comet to form the tail is ever recovered by the comet, so that comets seem to be continually disintegrating.

Perhaps I have mentioned something here that is entirely new to you. We are all familiar with wind pressure and we make use of it in the operation of our sail boats and our wind-mills; we all know about air pressure and steam pressure, which we use in numerous ways. But did you ever hear of light pressure? Did you realize that when the sun shines on an object it actually pushes on it? Of course the amount of this force is very small in comparison with the force of gravitation but if the particles upon which it is acting are small enough light pressure may actually overcome gravitation.

A piece of sand stone weighing fifty pounds will resist the pressure of a strong wind because the force of gravity will hold it on the ground but if it is crushed into very small particles the wind will blow it away although its actual weight has in no way been reduced. In like manner light pressure, which varies directly as the surface of the particle upon which it is acting, may overcome gravitation which varies as the weight.

COMETS ARE RECOGNIZED BY THEIR ORBITS

Small comets are generally designated by numbers which show the year in which they appeared. For example, the first comet to be seen in the year 1933 would be called 1933a. How-

ever, when a remarkable comet comes along it generally bears the name of the man who discovered it or of someone who has made a special study of its motion. The most famous example of this type is Halley's Comet.

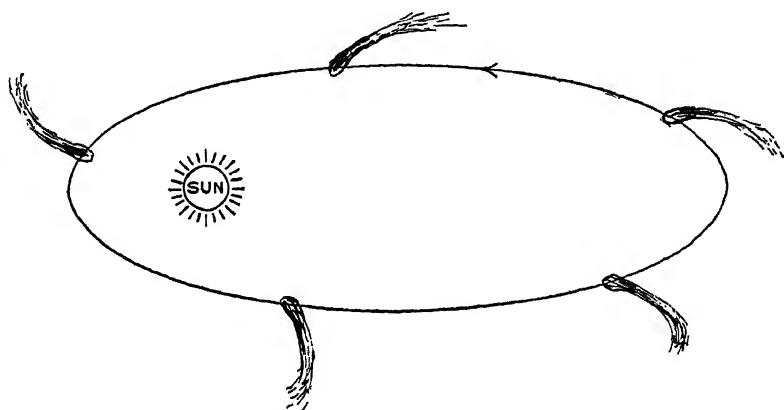
How can a comet be recognized after an absence of several years? Surely not by its general appearance, since this is frequently changed beyond recognition within a few days. This identification is made by means of its orbit. The ideas of primitive peoples with reference to these orbits were very vague. Many philosophers taught that comets were visitors who were prowling through the atmosphere of the earth bent on mischief. As a matter of fact, we are now convinced that comets are not in our atmosphere at all but that they are moving around the sun just as the planets do, each comet having a certain definite period at the expiration of which it will be back to the vicinity of the earth.

Perhaps you are wondering how Halley's comet could belong to the sun when it requires about seventy-five years to make one trip around that central body. We should remind you, however, that there are two worlds in the sun's family which require more time for a circuit around the sun than Halley's comet. In view of the fact that Halley's comet in its seventy-five years of wandering does not get much farther from the sun than the planet Neptune, it is obvious that there is plenty of room in the solar system for comets with periods of thousands of years. The fact that mathematicians can tell us at any time the exact position in space occupied by Halley's comet, although we have not seen it since 1910, is another triumph for that queen of the sciences—mathematics.

Since the orbits of comets are in general much flatter than the orbits of planets, they go much closer to the sun. When they cross the orbit of the earth as they go toward the sun or away from the sun, we may be so situated in our orbit that we can see them, but many comets swing around the sun without being seen on account of the distance.

COMETS SOMETIMES CHASE EACH OTHER ALONG SAME TRACK

Although comets belong to the sun's family, they are not always regular in their motion and behavior like planets. Encke's comet, which was first observed in 1786, has come back around the sun regularly every three and one-third years since its discovery, but at each visit since 1868 it has shortened its period



SEVERAL COMETS SOMETIMES
MOVE IN THE SAME ORBIT.

about two hours, possibly due to its passage through some resisting medium near the sun. Comets that travel across the entire solar system in orbits extending beyond the planet Neptune are certain, sooner or later, to encounter one of the planets in such a way as to have their motion completely altered. When a comet gets too close to a planet its motion is sure to be disturbed to some extent. Its period is usually shortened and its average distance from the sun decreased. However, this near approach may have just the opposite effect for a comet may be thrown entirely out of the solar system by one of the large planets.

After we have made a special study of the orbit of a comet we sometimes find that this orbit is the same as that of some other comet. In other words, certain comets seem to chase each other along exactly the same orbit around the sun at intervals of a few months or years. Such comets are known as groups of comets. One such group is composed of the great comets of

1668, 1843, 1880, and 1882. Each of these comets came from the direction of Sirius, passed half way around the sun with an enormous velocity, and then vanished in the same direction from whence it came. Such a group of comets probably had a common origin. Perhaps a single comet was at one time moving in this orbit and was broken into several parts by the attraction of the sun or the planets.

When comets come within the vicinity of the earth they of course reflect the light of the sun just as planets do. However, most of the light from a comet seems to originate within the comet itself and this light varies considerably from day to day. It does not seem reasonable to suppose that the material in a comet is heated to such an extent that it would shine by its own light, so that the light which is emitted by a comet is probably due to electrical discharges or to some other unknown cause.

COMETS HAVE VERY LITTLE WEIGHT

How much does a comet weigh? This question is very difficult to answer at the present time because we do not have weighing machinery that is sufficiently delicate. We can, however, fix an upper limit to the weight of a comet. Lexell's comet of 1770 came close enough to the earth to change the length of our year, if it had weighed anything, and in 1779 it got too close to the giant planet Jupiter and was apparently thrown out of the solar system. It would take at least a million comets as heavy as Lexell's comet to weigh as much as the earth. Brooks' comet of 1886 passed between Jupiter and its first satellite without affecting in any way either Jupiter or the satellite, but the comet was captured by the planet, its period being reduced from twenty-nine years to seven years.

The mean density of a comet is very low. In fact it is lower than the best vacuum we can produce under our air pumps. We can see stars through the head of a comet. The density of the tail is infinitely lower than that of the head. If we should expand a ball of gas one inch in diameter until it is the size of the earth's orbit its density would be comparable to that of a comet.

When we say that Jupiter "captured" Lexell's comet we do

not mean to infer that its orbit was changed in such a way that it now revolves around Jupiter instead of the sun. The comet still belongs to the sun but its period was reduced to such an extent that its orbit now lies entirely within the orbit of Jupiter.

When we investigate the chemistry of comets we discover that they are made of the same materials that we find in the earth. The most abundant element is carbon and it is interesting to note that this element which is absolutely necessary for the existence of life should be carried throughout the length and breadth of the universe by comets. Several times each century the earth passes through the tail of a comet. Other worlds certainly have this same experience. What it would mean to another world of just the proper temperature to be immersed in cometary matter for a period of several hours after the comet had picked up millions of life germs from the earth we can only conjecture.

SEVERAL REMARKABLE COMETS HAVE APPEARED IN RECENT YEARS

In 1826 Biela's comet was discovered and its period was computed to be almost seven years. It was observed at each return until 1845 when it came back in two pieces. The next time it was due it failed to appear, but the earth went through a shower of meteors when the comet was due in 1872 and again in 1885 and 1892. This is a powerful argument in favor of the final disintegration of comets. In fact it now seems certain that comets are only temporary bodies which sooner or later must break up into smaller comets or into showers of meteors which will ultimately fall upon one of the planets and be absorbed by the permanent members of the solar system.

In February 1843 a brilliant comet appeared which was visible in the day time and attracted so much attention in New England that \$25,000 was raised by public subscription for a large telescope at Harvard University. This was the largest instrument in America for some time. With this telescope Professor William Bond, five years later, discovered Hyperion, a new satellite of Saturn, the first heavenly body to be discovered by an American.

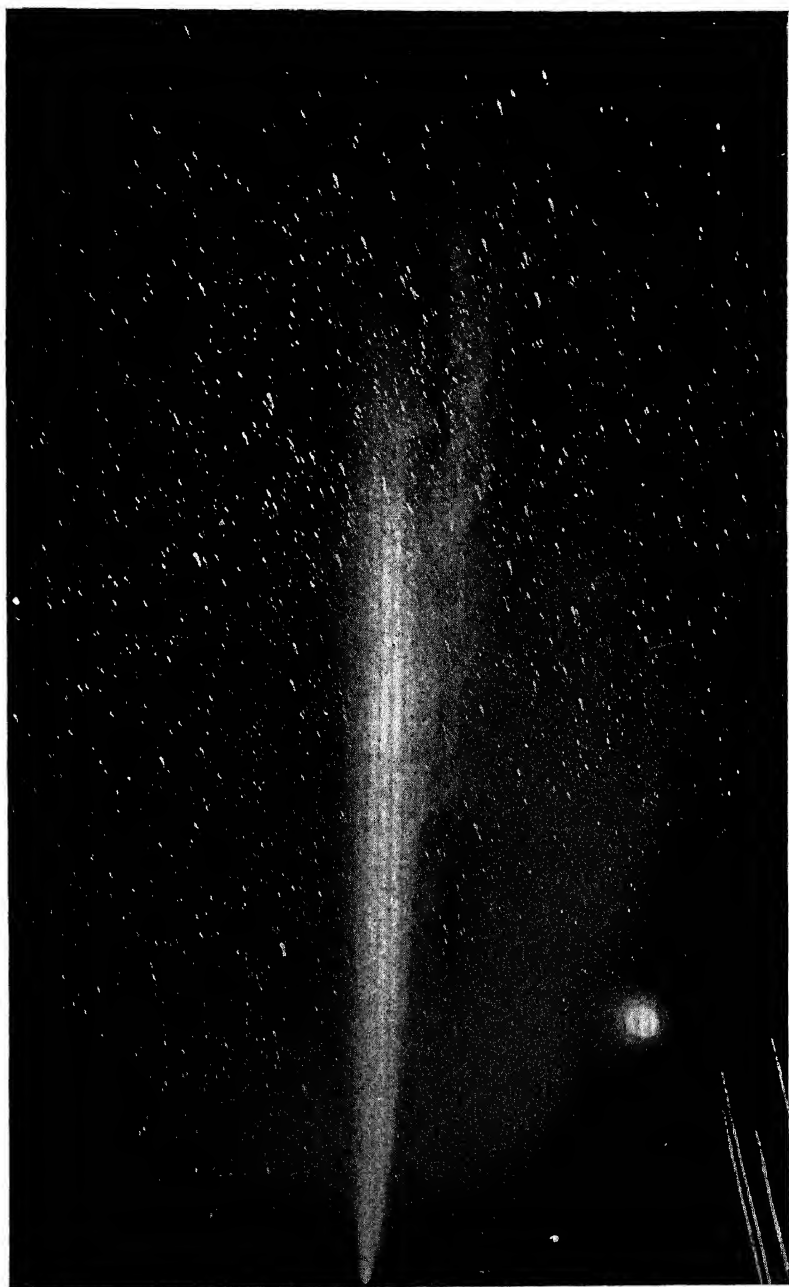
Donati's comet, which appeared in 1858, was visible without optical aid for 112 days. Its period is more than 2000 years. In September 1882 another brilliant comet appeared which was visible to the unaided eye in the day time for three days. This comet, with a tail 200 million miles long, went so close to the sun that it actually passed through the corona and its nucleus was broken into several parts by the solar attraction.

The most recent bright comet was Halley's comet of 1910, which comes within sight of the earth every seventy-five years. This was the first periodic comet whose return was predicted, its orbit having been worked out by Halley in 1682. Many of the large comets which terrified people during the Middle Ages were simply periodic appearances of Halley's comet. On this list we find the comets of 1456 and 1066, and the comet of 11 B. C., which some people identify with the Star of Bethlehem. The motion of Halley's comet in the past has recently been made a matter of special study and the date of every visit of this comet to the vicinity of the earth since 240 B. C. has been determined, and in most cases verified, by Chinese records.

METEORS WERE OBJECTS OF TERROR TO EARLY MAN

Occasionally an object resembling a ball of fire falls upon the earth out of the sky. Here again was another "sign" from heaven which, like a comet or an eclipse, was an object of terror to the superstitious people of early times. Of course we of the twentieth century are also afraid of these objects, some of which weigh several tons, and we do not like to think about what would happen if one should fall in the center of one of our large cities, but after it has fallen in the ocean or on some desert plain, we are no longer worried because the danger from that particular fire-ball is past.

Naturally we do not consider the fall of a meteor as warning of some impending catastrophe, neither do we agree with those primitive peoples who interpreted a meteoric shower as the result of the bad angels throwing rocks at the good angels. These bodies are known as meteors and are travelling in orbits around the



Halley's Comet and Venus, May 13, 1910.—Lowell Observatory.

sun just as the earth does. We are unaware of their presence unless they happen to collide with the earth. In this case they become visible because of the intense heat which is generated by their rapid motion through the atmosphere.

For convenience we usually divide meteors into two classes—shooting stars and meteorites. If they are so small that they are completely consumed by the terrific heat, we call them shooting stars. On almost any clear evening it is possible to see several of these small starlike objects dart across the sky and then disappear from view. Those meteors that are large enough to survive this collision with our atmosphere finally strike the earth and we then call them meteorites. Occasionally a blazing fire-ball flashes out in the sky followed by a luminous train. We see a flash, hear a report and then find a piece of stone or iron buried in the ground.

We find many examples of the worship of meteorites by superstitious peoples. A stone that fell in Phrygia is said to have been moved to Rome with great ceremony in 204 B. C. and worshipped as "the mother of the gods." The Indians in the northern part of Texas are said to have worshipped a stone which they believed had been sent to them by the Great Spirit. Probably some of their ancestors had actually seen this meteorite fall.

METEORS BELONG TO THE SOLAR SYSTEM

The average person is accustomed to thinking of the solar system as being composed of the sun, the planets and their satellites, but meteors, shooting stars and comets also hold membership in this celestial family. When we pick up a piece of a meteor or pass through the tail of a comet we have probably met, not a stranger, but one of our own immediate family. Until very recently all of these heavenly bodies were revolving about the sun.

We feel sure that most meteors do belong to our solar system because, although they contain about thirty known chemical elements, they do not contain any elements with which we are not already familiar. A meteor that fell in Russia in 1887 was composed largely of carbon. Their slow velocities would also indicate that the majority of them do not come to us from beyond the

solar system. However, a recent study of their velocities raises the question as to whether some of them may not come to the vicinity of the earth from distances equal to that of the stars.

Meteors strike our atmosphere with an average velocity of about twenty-six miles a second. Since the earth is moving about



A meteor and a nebula.—Yerkes Observatory.

eighteen miles a second those meteors that collide with our atmosphere early in the morning when we are on the front side of the earth have an apparent velocity of about forty-four miles a second, while those that overtake us in the evening appear to be moving with a speed of about eight miles a second. Of course this velocity is very rapidly reduced by the friction in the atmosphere and cases have been known where small meteorites have fallen on thin ice and rebounded.

Some authorities maintain that meteors are simply the fragments of material which were left over when the solar system was made. They tell us that after the passing star had pulled enough material out of the sun to form the solar system, most of this

material finally collected in certain centers and formed the planets and moons and that the remaining material is still revolving around the sun and furnishing the celestial fireworks which we call meteors. By comparing the relative amounts of helium and radium contained in meteorites, Professor Fritz Paneth concludes that the ages of meteorites vary from 100 to almost 3000 million years, so that some of them may be older than the earth itself.

METEORS MAY BE DISINTEGRATED COMETS

Meteorites must have been falling upon the earth almost from the very beginning and of course they have been recognized from remote antiquity. We find in the Old Testament several references to the fall of meteorites and the Chinese claim to have records of meteoric falls as early as 687 B. C.

Where do meteors come from? Many attempts have been made to answer this question. Some have suggested that meteors were perhaps projected from lunar volcanoes ages ago and that they have been moving around the sun like planets since that time. The theory that meteors result from the disintegration of comets is very popular today, since several comets have actually been seen to break up.

There seems to be no question but that there is a very close connection between comets and meteors. In fact the head of a comet is not a single solid mass but it seems to be made up of a multitude of small pieces. As the comet makes its regular trip around the sun it may perhaps be pulled to pieces and caused to disintegrate by the gravitational attraction of other heavenly bodies. Biela's comet was actually seen to make several trips around the sun, but it finally came back broken in two pieces. When it was again due it failed to appear and the earth passed through a shower of meteors in 1872 and in 1885 which were moving in the path of the comet and which were supposed to have resulted from its disintegration.

When we investigate the chemical composition of meteorites we find that most of them are stones with a peculiar internal structure. About three per cent of the total number are composed

largely of iron alloyed with nickel but traces of many other known metals, including even platinum and gold, are found, showing that the meteors and the earth probably had a common origin. The recent announcement by Professor Lipman of the discovery of bacteria existing inside of meteorites naturally aroused much interest and discussion, for if bacteria are found in meteorites then we are forced to admit that there is a possibility of the existence of life germs throughout the length and breadth of the solar system, unless we assume that these bacteria made their contact with the meteorite after it had finished its wanderings through space and had fallen upon the earth. This discovery has not yet been confirmed.

TWENTY MILLION METEORS STRIKE OUR ATMOSPHERE DAILY

How often do meteors strike the earth? Do they ever strike twice in the same place? What are our chances of being hit? These and similar questions are frequently asked by people who like to take every precaution against accidents. With our means of rapid communication we now hear frequent reports of meteors and we are beginning to realize that an enormous number of these projectiles are actually plowing through our atmosphere and falling upon the earth.

It has been estimated that more than twenty million meteors strike the atmosphere of the earth every day, there being about twice as many per hour in the early morning when we are on the front side of the earth as in the evening when we are on the back side. After midnight we observe both those meteors which the earth meets and also those it overtakes. Before midnight we observe only those which overtake us. Each of these meteors has been moving through space for ages and would still be pursuing its orbit around the sun had it not collided with the earth. The total amount of meteoric matter that falls on the earth must be very large, but it is so insignificant in comparison with the enormous weight of the earth that it has no effect either on the earth's rotation or on its period of revolution about the sun.

In the course of a year only about a thousand meteors survive

the heat generated by the collision with our atmosphere and actually fall upon the earth. Each of these meteorites represents the death and burial of a flying stone, which for many æons has been traveling around the sun in obedience to the law of gravitation—probably as a part of some comet. Very few of these are actually seen to fall because only a small part of the earth's surface is inhabited by civilized people—the earth is more than three-fourths water. Four or five times a year a meteor is observed to fall and it is usually found and dug out of the earth within a few days. The mass that falls is sometimes one piece but more usually there are many fragments sometimes counted by the thousands and scattered over a rather wide area. At the present time we have specimens of more than three hundred meteorites which have actually been seen to fall, about thirty of these having fallen within the United States.

AN ENORMOUS METEORITE LIES IN ARIZONA

Some parts of the moon's surface are literally covered with craters which many people believe have resulted from the impact of large meteors ages ago. If the moon were subject to this bombardment from the depths of space, then certainly the earth could not have escaped, and it will be of interest to study its surface to see if we can find any craters that might be of meteoric origin. Of course the earth has an atmosphere which only the largest meteors can penetrate without being burned up and which also makes erosion possible, so that meteoric craters are soon erased from the permanent features of its surface.

The largest meteoric crater that has been found on the earth is the famous Meteor Crater in Arizona which resembles very closely those on the moon, although on a much smaller scale. Scattered about the rim are millions of tons of white lime stone, crushed to the fineness of talcum powder, and thousands of pieces—several tons of material—of meteoric nickel-iron have been picked up within a radius of six miles. Surely this is convincing evidence of the meteoric origin of this great pit, for nowhere in the world have so many meteorites been found on such a small area.

As one stands on the edge of the rim of Meteor Crater and looks across at the opposite wall almost a mile away, and then at the level bottom about 500 feet below, he realizes that at some vague time in the dim distant past a gigantic visitor from the depths of space here found a grave. What an enormous mass it must have been to be able to bore a hole in the solid earth a mile wide and then bury itself in the ground, leaving a great bowl 500 feet deep!



Meteor crater in Arizona.—From Moulton's "Astronomy." By permission of the Macmillan Company, publishers.

Recently a square shaft has been sunk in the bottom of the bowl to a depth of 700 feet and the celebrated Arizona Meteorite has been found. An examination of the borings that have been made into the hard object at the bottom of the shaft discloses the fact that this meteorite contains a large amount of nickel like that which has been picked up around the outside of the rim. What an enormous amount of energy must have been expended by this flying piece of nickel-iron when it dug its grave a quarter of a mile below the surface of the earth!

A COMET MAY HAVE STRUCK CAROLINA

Soon after the Arizona Meteorite was located in its grave a quarter of a mile below the surface of the earth, scientists began to search for other "craters" that might have resulted from the

impact of meteors. In 1895 their attention was called to the Carolina "bays"—a group of hundreds of depressions along the coast of North and South Carolina—which may have been of meteoric origin. Perhaps an immense comet struck that part of the earth ages ago.

From Norfolk, Virginia, to the Savannah River, a distance of about 400 miles, are to be found at least 3000 indentations, some of which are more than a mile in diameter. The southeast rim of these pre-historic craters is in most cases higher than the northwest rim and the craters are elliptic in shape, which probably means that the swarm of meteors which composed the original comet was moving from northwest to southeast when it struck the atmosphere of the earth and plunged into the soil of the Carolinas. Of course we have no proof that these curious formations resulted from the collision of our earth with a comet—and some people claim that they are merely shallow lake beds with sandy rims formed by the winds—but the cometary theory seems to offer a very plausible explanation. These formations cover an area of 190,000 square miles which may have been the area of the cross-section of the comet.

At Odessa, in western Texas, is a crater about 530 feet in diameter which is undoubtedly of meteoric origin. From the soil in its vicinity more than 1500 metallic fragments have been collected, and in all probability a huge meteor lies buried here. One is tempted to suggest that perhaps in prehistoric times a comet fell in the Atlantic and sprinkled the Carolinas with meteors, and that the earth's rotation brought Texas and Arizona into the danger zone just in time to catch two lagging components of the comet. Let us hope that the celebrated Halley's comet never falls on a densely populated section of the earth's surface.

In Central Siberia, where a small comet fell in June 1908, there is a group of ten craters having an average depth of about ten feet and whose diameters vary from thirty to 150 feet. In Central Australia is a group of thirteen craters, the largest of which is about 660 feet long, 360 feet wide and about 50 feet deep. Here hundreds of pieces of meteoric iron have been found.

SEVERAL LARGE METEORS HAVE BEEN
RECOVERED

Until the gigantic Arizona Meteorite has been uncovered and brought to light, the distinction of being the world's largest meteorite belongs to the Grootfontein Meteorite which was found in South West Africa several years ago and must weigh at least fifty tons. Dr. W. J. Luyten recently examined this meteorite and reported that it is "An enormous block of metal, almost rectangular in shape, of dimensions nine by ten feet, and of thickness varying from two and a half to almost four feet." A pit has been dug around the meteorite but its "nose" is still buried deep in the rocks and only a rough estimate of its weight has yet been obtained. It contains about seventeen per cent nickel and eighty-one per cent iron. Dr. Luyten reports that this alloy is so tough that it required "fully two hours of sawing and more than a dozen hacksaw blades to saw off a piece with a surface of only two square inches."

The Greenland Meteorite that Admiral Peary brought back from one of his Arctic trips and placed in the American Museum of Natural History in New York weighs $36\frac{1}{2}$ tons and two meteorites have been found in Mexico that weigh about twenty-eight tons each and another in Oregon that weighs about sixteen tons. In South West Africa is a valley that has been peppered with small meteors, about fifty of which have been dug up and preserved. These meteorites are all of about the same size, weighing about 500 pounds and containing about seven per cent of nickel.

For convenience meteorites are divided into two classes—stone meteorites and those composed largely of iron. By a curious coincidence the largest known meteorite of each type, whose "fall" was actually observed, struck the earth in Arkansas. Early in the morning of February 7, 1930, a huge stone weighing 820 pounds fell near Paragould and was found about five weeks later. This meteorite measures 26x36 inches and is now in the Field Museum at Chicago.

In 1886 an iron meteorite weighing 107 pounds was seen to fall near Cabin Creek, Arkansas. It is said that lightning never strikes twice in the same place, but we are never sure about

meteors. At any rate, soon after this huge piece of iron struck Arkansas near Cabin Creek the inhabitants of this thriving little village had its name changed to Lamar, and Cabin Creek has disappeared from our maps.

METEORS ALWAYS ATTRACT ATTENTION

A shooting star attracts the attention of every casual observer and a fire-ball, with its long trail of light and its hissing noise with sometimes a loud explosion, will arouse the countryside. The largest fire-ball that has flashed across the sky within the memory of man was probably the meteor that fell in Siberia on June 30, 1908. This enormous ball of fire was seen by observers at a distance of 450 miles, to whom it appeared to be about half the size of the full moon. It probably exploded before striking the earth, for the ground in the vicinity of the place where it fell shows evidence of having been bombarded by many meteors, each of which buried itself in the ground. All vegetation in the immediate vicinity of this spot seems to have been burned up. Trees were blown down and everything in the path of the meteor was completely destroyed by fire.

When the 820 pound stone fell near Paragould, Arkansas, on February 17, 1930, the noise was so great that people in Arkansas, Tennessee and Missouri were awakened from sleep, and many were panic stricken. The violent detonations sent the police force of a city seventy miles away on a hurry call to all of the banks to catch the robbers who were believed to have dynamited a safe. From the same town went out a report that the boiler of a locomotive had exploded.

Early in the morning of March 24, 1933, the people of New Mexico, Oklahoma, Kansas, Texas, Arizona and Colorado were awakened by a terrific explosion, accompanied by a brilliant flash of light. The detonation was so great and the light was so bright that people several hundred miles apart believed that a meteor had fallen very close to them. As a matter of fact this terrific explosion was caused by a fire-ball that struck the atmosphere of the earth and exploded over the northeastern part of New Mexico. The meteor burst into fragments but a cloud

of meteoric dust remained in the atmosphere and was visible until long after sunrise.

Less than a month later, on April 20, 1933, an unusually brilliant meteor with a greenish tint was seen from all parts of



The Paragould Meteorite.—Courtesy of *Popular Astronomy*.

Oregon and Washington. This fire-ball first became visible over southern Oregon and traveled a little east of north, passing over Yakima, Washington. About thirty miles beyond Yakima it burst into fragments and disappeared.

METEORITES ARE USUALLY NOT HOT

When meteors appear in the upper atmosphere of the earth they have the appearance of being on fire and are frequently called fire-balls. One would naturally suppose that these objects would continue to blaze until they strike the earth and this view was at one time accepted even by scientific men, but in recent years a number of meteorites have actually been seen to fall and have been examined very soon after they struck the earth.

Contrary to the generally accepted view, we find that most meteorites are cold when they reach the earth's surface. Although they have been very hot they cool down quickly in the lower atmosphere and when they fall on the earth they are often just a little warm to the touch. Iron meteorites will be on the average hotter than stones for obvious reasons.

The Paragould Meteorite, which was the largest ever seen to fall, disappeared at an altitude of about five miles. In other words, although it was at one time a fire-ball it cooled down by the time it got within five miles of the surface of the earth. If meteors always strike the ground as balls of fire we would have occasional conflagrations that might be traced to this source. From time to time we hear a report of houses having been burned by a meteor but when these rumors are investigated carefully they are always found to be unfounded. The consensus of scientific opinion today seems to be that, although iron meteorites may be too hot to handle when they strike the surface of the earth, the stone meteorites are never hot. In fact there is one instance on record where one of these stones was found in moist earth and covered with ice.

Not only does the lower atmosphere of the earth cause a meteor to cool down but it also reduces its speed so that it does not bore a very deep hole in the earth. As a general rule we may expect a heavy meteor to penetrate deeper into the earth than a lighter one, but this is not always the case for the depth to which a meteor penetrates depends upon several other factors in addition to its weight. Meteors that collide with the earth are moving much faster than those which overtake us and consequently will penetrate more deeply, and those that strike the earth vertically will go deeper than those falling at an angle.

METEORS ARE A SOURCE OF DANGER

Of course we do not agree with early peoples who believed that meteors fell out of the sky only when the good angels threw rocks at the bad angels, but still it is a comfortable feeling to realize that the earth is surrounded by an atmosphere that protects us from these celestial projectiles by burning up all the

little ones so that only the large ones are a source of danger. Some of these explode in our atmosphere so that they do not strike the earth and the others, up to the present time, have fallen in the open country without injuring anyone.

The American Meteor Society is very active in the recovery of meteorites and has recently published a list of thirty of these projectiles which, within the last quarter of a century, have fallen in Alabama, Arkansas, Arizona, Colorado, Georgia, Idaho, Illinois, Kansas, Kentucky, Michigan, Minnesota, Mississippi, Missouri, Nebraska, Nevada, North Carolina, North Dakota, South Carolina, Texas, Virginia, Wisconsin and Wyoming. These flying stones are a constant source of danger. We can imagine what would have been the result had the 820 pound Paragould stone fallen through the roof of one of our city apartments in February 1930 rather than on a farm in Arkansas. What if the forces of nature had hurled the comet of June 1908 into a densely populated district instead of dropping it on a lonely spot in Siberia!

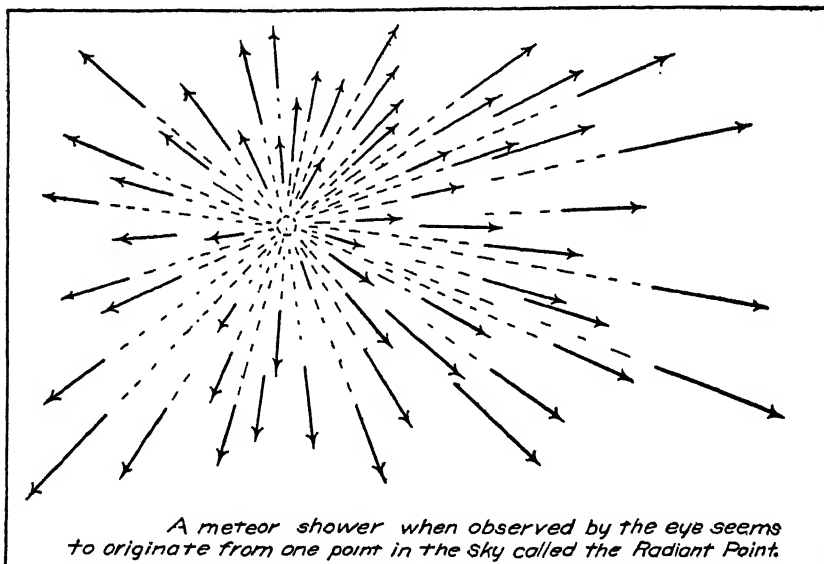
It is indeed remarkable that, although these stones have been falling upon the earth since the advent of man, we have only one or two more or less authentic records of anyone having been killed by a meteorite. One of these instances is recorded in the tenth chapter of the Book of Joshua where we are told that "great stones from heaven" fell upon the children of Israel and slew them. There is also a record of a person in India having been killed by a meteor.

Fortunately, up to the present time, we have been able to dodge these flying projectiles—at least modern history contains no record of any casualties from this source—but the meteorite that fell near Athens, Alabama, on the morning of July 11, 1933, struck the ground close enough to a farmer to convince him that falling masses of stone and iron really are a source of danger. This stone fell with a whizzing noise less than thirty feet away and was still warm when he dug it up.

SHOOTING STARS ARE NOT STARS AT ALL

Did you ever see a star shoot? Perhaps you think you have but really you have not. Shooting stars are very small and are in

our atmosphere like the clouds. Real stars are as large as the sun and are at such an enormous distance that, when expressed in miles, the figures have no meaning to the human brain. If you should ever happen to be looking at one of the fixed stars and see it shoot across the sky, you would be justified in looking upon this as a sure "sign" that something terrible is about to happen.



It is rather unfortunate that meteors which are entirely consumed in the atmosphere of the earth are called shooting stars. They are not stars at all. Most of them are so small that they could be held in your hand. It may seem strange that such small bodies should have regular orbits and obey Kepler's Laws, but they must. There is nothing in the smallness of a body to excuse it from obedience to mathematical laws.

Sometimes shooting stars appear in showers of thousands or even millions. At such times they do not move at random but appear to radiate from a single point in the sky. Each of these showers carries the name of the constellation from which it appears to radiate. After computing the orbit of a meteoric shower we frequently find that these meteors are moving in the same orbit with one or more comets. This is just another argument in favor of the final disintegration of comets.

Meteoric showers from the same point in the sky recur on or about the same day every year. The Leonids have a bluish-

green tint and radiate from the constellation Leo about November 15. These meteors move around the sun in a direction opposite to that of the earth, which accounts for their high velocity and for the fact that we see them during the morning hours. The Andromedes, moving in the orbit of the lost Biela's Comet, are of a reddish color and appear about November 24 from the constellation Andromeda. They move in the same direction as the earth and strike our atmosphere during the evening hours with rather low speed. The Perseids are yellow and come from the direction of the constellation Perseus about August 11. The Lyrids from the constellation Lyra will be seen about April 20 every year.

THE STARS FELL BY THE THOUSANDS IN 1833

The most impressive meteoric shower that has ever occurred was probably that of the Leonids on the night of November 12, 1833, when it was estimated that at least ten thousand stars fell every hour for five or six hours. Our grandparents and great grandparents referred to this year as "the year the stars fell."

Immediately after the shower of 1833 Professor Olmsted of Yale University called attention to the fact that these meteors all radiated from the same point in the sky. The mathematicians then attacked the problem of determining when it would occur again. It was found that the meteors which fell in 1833 belonged to a swarm which was moving around the sun in an elongated elliptical orbit nearly two billion miles long. Meteors are scattered all around the orbit, forming a complete ring around the sun. The orbit of the earth crosses this ring and every November the earth plows through the swarm. Those with which we collide are completely burned in the atmosphere of the earth. They are called the Leonids because they seem to be coming from the direction of the constellation Leo.

All of the meteors in this swarm are rushing headlong through space and complete their circuits around the sun in about thirty-three years. Although they are completely scattered around the ring there seems to be one place where they are very thickly concentrated and this dense swarm must appear at

the "orbit crossing" every thirty-three years. This was what the earth encountered in 1833.

After tracing this meteoric shower back about two thousand years the mathematicians predicted that the stars would fall again in 1866 and the shower came in November of that year, although the stars were not as numerous as in 1833. This was due to the fact that America was on the front side of the earth when it plowed into the swarm of meteors in 1833, while Asia was on the front side when we struck the swarm again in 1866. The attraction of the planet Jupiter seems to have changed the orbit of these meteors so that we did not have this collision in 1899 when next due and we are probably safe for many years to come.

THE DRACONIDS FELL IN 1933

On the night of Monday, October 9, 1933, there occurred a meteoric display which, in some parts of the world, seems to have surpassed the brilliant star-showers of 1833 and 1866. Although this October display was not announced in advance and was "all over" in just a few hours, the flying meteors plunged into our atmosphere in sufficient numbers to attract attention in Europe, Asia, Africa, America and perhaps other parts of the world.

Unfortunately, America was not very well situated for witnessing this unexpected celestial performance for all of the "box seats" seem to have been on the other side of the globe. The falling "stars" were very numerous at Malta, where it was estimated that for a short time 480 meteors a minute were thrown into our atmosphere from the direction of the constellation Draco. In Ireland the meteors were said to have fallen as thickly as flakes of snow in a snow storm, several Russian observers reported more than 100 meteors a minute and in Syria 168 shooting stars were counted within a period of thirty minutes. About five hours after the shower had reached its maximum in Europe some of the meteors struck different parts of the United States, but by this time the display was practically over and only one American observer reported having seen as many

as ten meteors a minute during the short time the stars were falling.

Immediately after this October display astronomers identified the comet to which these meteors belonged, for they came from the direction of the constellation Draco and were apparently moving in the same path with Giacobini's Comet which astronomers had been watching for about six months. Fortunately the comet passed this point of its orbit in July and thus escaped what might have been a direct collision, but some of the material distributed along its path came within the earth's atmosphere when we were closest to the orbit.

The meteoric shower of October 9, 1933, should not be confused with the Leonids which appeared five weeks later. The October shower belongs to Giacobini's Comet with a period of seven years, while the November meteors move in the orbit of Temple's Comet with a period of about thirty-three years. The Giacobini meteors move in an entirely different orbit from the Leonids and in the opposite direction. They come from the direction of the constellation Draco, while the Leonids always radiate from the direction of Leo.

NEW STARS FORETOLD HAPPY EVENTS TO PRIMITIVE PEOPLES

Primitive man looked upon eclipses of the sun and the moon as expressions of the grief of nature and he believed that comets were placed in the sky and fire-balls were thrown upon the earth to give him due warning of some impending disaster. However, his life was not entirely one of gloom and despair. There were "signs" in the heavens that foretold happy events which were in store for mankind.

Upon certain occasions a new star would blaze out in the sky at a place where no star had ever been seen before in order to express nature's delight at some happy event of the greatest importance that was soon to occur. The Sacred Books of India tell us that the birth of Buddha was announced by heavenly lights and from the Sacred Books of China we learn that the birth of the founder of the first dynasty was foretold in like

manner. We also learn from ancient literature that the births of Moses, of Aesculapius, and of the various Cæsars were announced by temporary stars. According to a Jewish legend the birth of Christ was foretold by a temporary star which was considered to be of sufficient importance to deserve a name—The Star of Bethlehem.

These temporary stars, which are even more numerous today than in early times because their existence can now be revealed by our powerful telescopes, are supposed to arise from the collision of two stars. We call them "novas" because they are new stars. About eighty novas have been observed during the last three hundred years, sixty of which appeared during the twentieth century. Modern astronomers are so well acquainted with the different sections of the sky that a temporary star is usually detected when it first appears on a photographic plate.

The earliest nova of which we have any authentic record appeared in the constellation Scorpio in 134 B.C. It was this temporary star that induced Hipparchus to make his catalogue of stars. Among the brightest novas that have appeared during the last few centuries were those of 1572, 1604, 1901, 1912, 1918, and 1934. Although we believe that two invisible dead stars may collide and form a nova, we of course understand that because of the great distance to the stars the collision which resulted in the bright nova in 1918 probably occurred before Moses was hidden on the banks of the Nile.

CHAPTER VI

The Story of the Stars

THE SKY IS NOT A MENAGERIE

PERHAPS you have examined some of the early star maps where the different groups of stars were arranged in the forms of animals and human beings, and you have wondered whether the sky really was a menagerie. On these maps of the sky we find

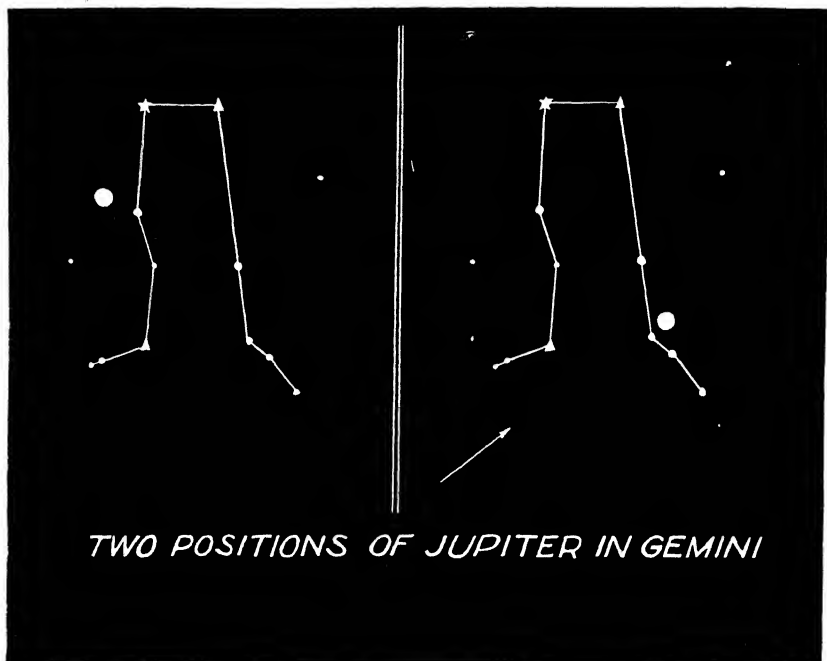


One group of constellations pictures the flight of the great hunter, Orion, across the heavens.

animals such as bears, dogs, serpents, sheep, bulls, lions, scorpions, fish, dragons, goats and eagles and also mythical heroes such as Orion, Hercules and Perseus.

It is natural to suppose that the moment primitive man began to observe anything he noticed the stars and it was necessary for him to have some way of defining the particular star, or group of stars, he would like to talk about. He naturally chose

the brightest stars and combined them in groups, which he perhaps believed to have some real connection, and named these groups after mythological characters and animals whose names were familiar to him and which played such an important part in his fairy tales and legends.



TWO POSITIONS OF JUPITER IN GEMINI

The ancients had no notion that these star-groups in any way resembled the animals after which they were named. Thus, when you are trying to find Orion, do not look for a group of stars which resembles a man. This star-group never did look like the great hunter Orion and never will. It got its name from one of the legends of classical mythology. The grouping of the stars into what we now call "constellations" is somewhat arbitrary, but our forefathers have followed the lead of our early ancestors and have added only such new constellations as were necessary to commemorate later events.

There are certain heavenly bodies that look like stars but are not really stars at all. These are the planets, which move about in the sky so that it would not be possible to include them in any star map. The objects which we call fixed stars, although

they are not fixed at all, do not change their relative positions during the life time of a human being and consequently maps of these stars may easily be made. The planets, or wandering stars, were recognized by ancient peoples both because of the fact that they move about from one fixed star to another and also because they always lie very close to a certain imaginary circle in the sky known as the ecliptic. Such wandering stars have nothing to do with our star maps and must be considered separately.

STAR-GROUPS HAVE BEEN CAREFULLY SELECTED AND NAMED

A study of early myths and legends makes it evident that the sky is not merely a collection of stars and constellations with names that have no meaning, but that each star-group has been carefully arranged by someone in such a way that history has been written indelibly in the open book of the sky where it will last forever. Thus we find recorded in the sky the beautiful story of Perseus and Andromeda and many of the other legends of classical mythology.

It seems certain that the constellations were not invented by the Greeks from whom we received them, but by a much earlier race. The earliest constellations must have been named in Mesopotamia for the animals are those mentioned in the Bible. They could not have been named in India for there is no tiger or elephant, and the absence of the crocodile and hippopotamus makes it extremely unlikely that they originated in Egypt.

The constellations must have originated after the famous Argonautic Expedition since many of them are named after the Argonauts. We may also assume that they were named before the fall of Troy because we do not find in the sky Achilles, Ulysses, Priam, Hector or any of the other heroes of the siege of Troy. They must have been familiar to the Greeks long before the days of the poets Hesiod and Homer for Hesiod in his "Works and Days" mentions the Pleiades, Arcturus, Orion and Sirius, and Homer sings about the Pleiades, the Hyades, Orion and the Bear . . . "which alone does not bathe in the ocean."

This celebrated poet of antiquity must have written his beautiful epics before man pictured Draco and the Little Bear in the sky for both of these constellations also glide silently around the North Pole and never disappear below the horizon.

Although most of our stories about the constellations have been derived from the Greeks, other peoples seem to have had



The members of the Royal Family are clearly pictured in the northern sky.—From Griffith's "Stars and Their Stories," by permission of Henry Holt and Company, publishers.

the same star-groups so that all of them probably derived their constellations from an earlier race. The Arabians certainly did not borrow any of their constellations from the Greeks. Yet they knew about the Great and Little Bears, the Dragon, Cassiopeia, Andromeda, Perseus, the Fishes, Auriga, the Ram, the Bull, the Twins, and many others. It seems very probable that the constellations were introduced by a nation coming from the East some time before 3000 B.C.

WE NOW HAVE ONE HUNDRED AND SEVENTEEN CONSTELLATIONS

About two thousand years ago a bright star suddenly blazed out in the sky where there had been no star before and the curiosity of the Greek scientist, Hipparchus, was aroused to such an extent that he made a catalogue of 1080 of the brightest stars so that new stars might thereafter be more easily detected. About three centuries later Ptolemy of Alexandria collected and published all known astronomical facts and theories and presented to the world a finished, though quite erroneous, system of astronomy which goes by his name, though the ideas were merely copied from earlier sources. As a part of this work Ptolemy reproduced the star catalogue of Hipparchus and described forty-eight constellations containing a total of 1026 stars. This is not the total number visible to the unaided eye, since we can see about 5000 stars without a telescope.

Some of the principal constellations in Ptolemy's catalogue were: the Ram, the Fish, the Whale, the Lady in the Chair, the Bull, the Charioteer, the Hunter, the Hare, the Twins, the Great Dog, the Little Dog, the Crab, the Lion, the Hydra, the Big Bear, the Little Bear, the Centaur, the Virgin, the Serpent, the Herdsman, the Northern Crown, Hercules, the Balance, the Scorpion, the Eagle, the Lyre, the Dragon, the Swan, the Bowman, the Sea-Goat, the Watering Pot and the Winged Horse. Since the time of Ptolemy sixty-nine constellations have been added. Perhaps the most interesting of these is the Southern Cross which is visible only in southern latitudes and is considered by some people as the most brilliant constellation in the sky. Dante, in his "Purgatory," refers to this beautiful constellation.

A thorough knowledge of the one hundred and seventeen constellations is not at all essential but everyone should be able to recognize the principal ones and to pick out at least twenty bright stars. This can be easily done by studying the sky with a star map a few minutes once a week for a year, thus allowing the sky to make one apparent revolution.

It is always interesting to study the origin of the names of the individual stars and star-groups. Here one is concerned not so

much with astronomy but rather with mythology and primitive religion. However, the Story of the Stars is such a fascinating tale that it may be told and re-told even at the expense of appearing unscientific.

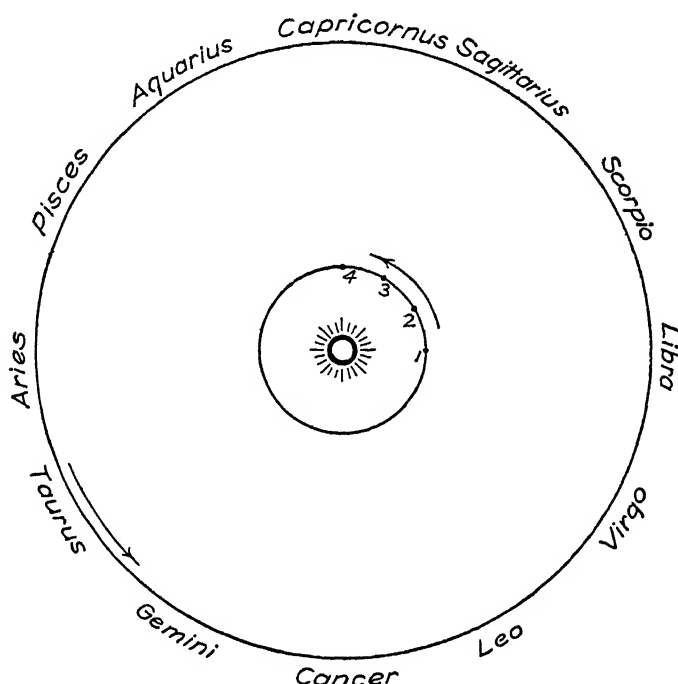
THE ZODIAC MARKS THE PATH OF THE SUN

The oldest scientific heirloom of the human race is probably the Zodiac which is generally supposed to have been invented by the Babylonians about 26,000 B.C. It has been known by many names in different countries. It has been called the Bestiary, in allusion to the menagerie of living creatures it contains. It has also been called Our Lady's Way, possibly as marking the course of the moon.

The Zodiac is the name given to a zone among the stars extending eight degrees on each side of the path of the sun. The name is derived from a Greek word meaning a "living creature." Although the Zodiac is now determined by the course in the heavens apparently pursued by the sun in his annual journey through the sky, it is very probable that it was originally determined by the path of the moon which follows very closely the path of the sun and which can be observed at the same time as the stars. The moon moves eastward among the stars at such a rate that it accomplishes a complete circuit of the sky in about twenty-eight days. The Zodiac was thus divided into twenty-eight parts, in each of which the moon spends one day. The Chinese, Arabs, and several other nations seemed to have used this kind of a Zodiac, in fact the Chinese word for "sign" of the Zodiac is said to be the same as their word for "hotel."

As the earth makes its annual swing around its orbit the sun is daily projected into a different part of the sky, making a complete circuit of the heavens in twelve months. Consequently, the ancient astrologers divided the Zodiac into twelve "signs," in each of which the sun spends one month. The names of these twelve signs are Aries, the Ram; Taurus, the Bull; Gemini, the Twins; Cancer, the Crab; Leo, the Lion; Virgo, the Virgin; Libra, the Scales; Scorpio, the Scorpion; Sagittarius, the Archer; Capricornus, the Sea-Goat; Aquarius, the Water Carrier; Pisces, the Fishes.

The Zodiacal Signs, used by the Japanese as early as the seventh century, were also named after living creatures as follows: Ne, Rat; Tora, Tiger; Tatsu, Dragon; Uma, Horse; Saru, Monkey; Inu, Dog; Ushi, Bull; U, Rabbit; Mi, Snake; Hitsuji, Sheep; Tori, Cock; Yi, Wild Boar.



As the earth moves through the positions, 1, 2, 3, 4 the sun appears to travel around a circle in the sky. The belt lying on each side of this circle forms the Zodiac.

THE SIGNS OF THE ZODIAC DIFFER FROM THE CONSTELLATIONS

It is necessary to make a distinction between the "signs" of the Zodiac and the "constellations" of the Zodiac. Each sign is exactly thirty degrees long—one twelfth of the complete zone—and the first sign (Aries) begins with the Vernal Equinox. That is, the sun always enters the sign of Aries as it passes through the Vernal Equinox. It then traverses Taurus and Gemini and enters Cancer at the Summer Solstice, after which it traverses

Leo and Virgo and enters Libra as it passes through the Autumnal Equinox. The sun then traverses the six signs south of the equator and enters the sign of Aries again when it arrives at the Vernal Equinox.

The twelve groups of stars (constellations) within the boundaries of the twelve signs originally had the same names as the signs, and each constellation would remain forever within the corresponding sign if the Vernal Equinox did not move among the stars. However, Hipparchus discovered (125 B.C.) that the Vernal Equinox is not a fixed point in the sky, but that it slowly slips westward along the ecliptic. What a close observer he must have been to make this discovery seventeen centuries before the invention of the telescope! This movement of the equinoxes, which is called "precession," carries the signs of the Zodiac westward around the ecliptic with a constant speed that causes them to make a complete circuit of the sky in 26,000 years. Thus the constellations of the Zodiac remain fixed but the signs steadily slip westward.

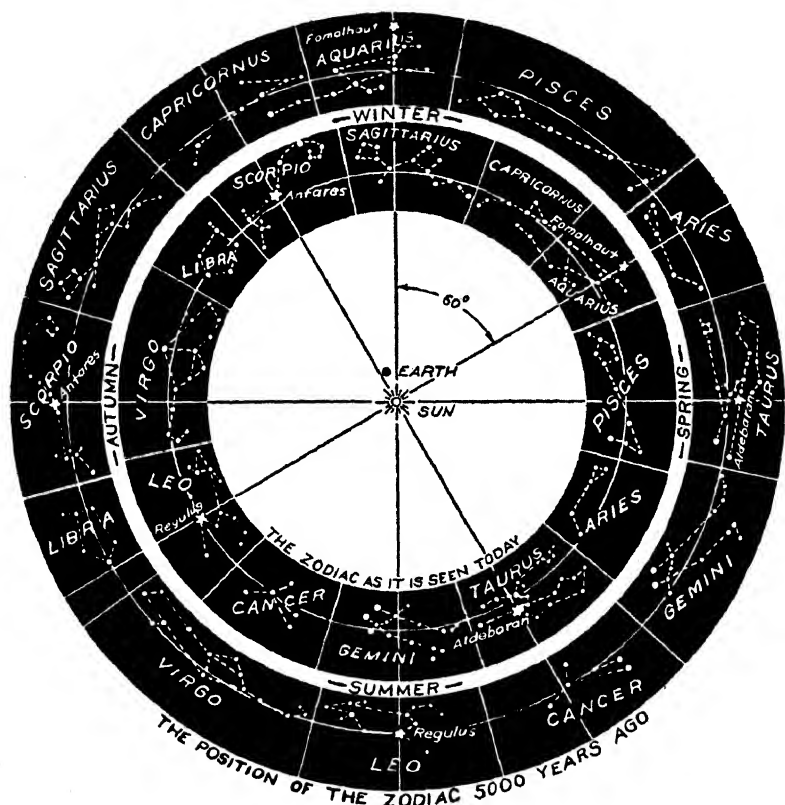
The sign of Aries is now in the constellation Pisces, each sign having backed into the constellation west of it in the last 2000 years. The signs and constellations of the Zodiac coincided about 300 B.C. and also about 26,000 B.C. We know they were in use before 300 B.C. They must, therefore, have been invented not later than 26,000 B.C. This gives us some information as to how long man has been studying the stars. How absurd to assume that the earth was created about six thousand years ago!

The Greek writer, Hesiod, says that Arcturus rises at sunset fifty days after the Winter Solstice. In our calendar this date would be February 19. This bright star now rises at sunset in Greece on March 30. From the known rate of the shift of the constellations of the Zodiac we can determine that Hesiod lived about 2800 years ago.

THE CHINESE FOUND FOUR BRIGHT STARS IN THE ZODIAC

We learn from the early writings of the Persians and the Chinese that there were four bright stars in the sky that pro-

tected and watched over the others. These stars were said to be in the east, the west, the north and the south. These positions evidently corresponded to the Vernal Equinox, the Autumnal Equinox, the Winter Solstice and the Summer Solstice—the four cardinal points of the sky. Let us see if we can identify these four stars that were so prominent in those early ages.



If we turn the Zodiac back to where it was 5000 years ago we find four bright stars in the four cardinal points of the heavens.

If we look into the sky in the vicinity of these four points we can find no stars of any considerable brightness and we perhaps may be inclined to doubt the accuracy of this ancient literature or to wonder whether the four bright stars have faded considerably during the intervening years. However, we must recall that, because of the westward precession of the equinoxes, the four cardinal points do not have the same location with reference to the stars as they had ages ago for the constellations

of the Zodiac are continually slipping in an easterly direction with reference to the Vernal Equinox. We must study the Zodiac as the Persians saw it.

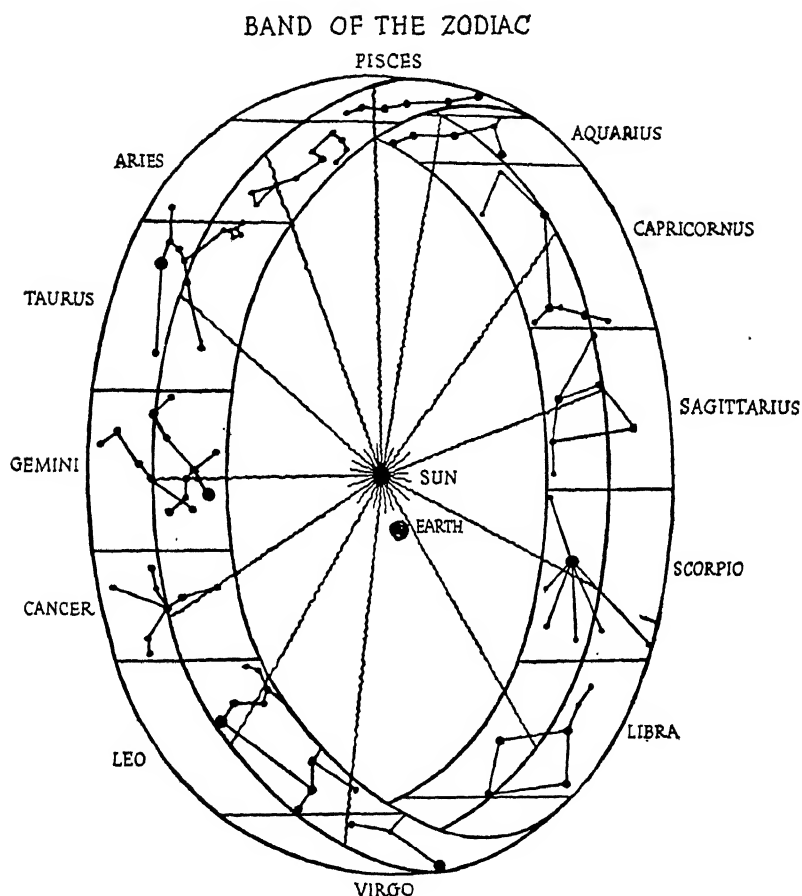
Suppose we turn the Zodiac back (westward) through sixty degrees. Imagine our surprise at finding four bright stars, Aldebaran, Antares, Regulus and Fomalhaut, almost exactly in the places assigned to them by the Persians. Since the Zodiac has slipped through sixty degrees in about 5000 years we can tell approximately when the observations of these ancient peoples were made.

Of the four bright stars that the Persians and Chinese said were in the four cardinal points of the Zodiac, Aldebaran is in the constellation Taurus (the Bull), Antares is in Scorpio (which Abraham and his followers called the Eagle), Regulus is in Leo (the Lion) and Fomalhaut is in the outskirts of the constellation Aquarius (which was usually represented by a man pouring water out of a vessel). It was, therefore, natural for early peoples to think of four living creatures—the Bull, the Eagle, the Lion, and the Man—as being situated in the four principal points of the Zodiac—the Vernal Equinox, the Autumnal Equinox, the Winter Solstice and the Summer Solstice. Although the Persians and Chinese seem to have been more interested in the four stars than in the constellations with which they were associated, the early Hebrew writers called special attention to the four living creatures.

BIBLICAL WRITERS PAINTED VIVID PICTURES OF THE ZODIAC

An interesting bit of evidence that the constellations of the Zodiac have been slipping around the Celestial Sphere since the very dawn of history is to be found in the Book of Ezekiel and in Revelation. To one who understands the story of the Zodiac and realizes how easy it would be to refer to this "girdle of the sky" as a "wheel," the following passages give a very vivid description of those four signs of the Zodiac which seem to have always been associated with the four living creatures—the bull, the eagle, the lion and the man—and which are lifted up one

after the other into the eastern sky as the rotation of the earth causes the constellations to rise and the wheel to appear to turn. The thousands of stars in the background furnish plenty of "eyes" for these four creatures.



WHEN THE SUN IS IN ARIES

It was only natural to refer to the Zodiac as a wheel which was constantly rotating.—From Griffith's "Stars and Their Stories," by permission of Henry Holt and Company, publishers.

Ezekiel (1:10): As for the likeness of their faces, the cherubims, they had the face of a man; and they four had the face of a lion on the right side; and they four had the face of an ox on the left side; they four had also the face of an eagle.

Revelation (4:6-7): And round about the throne, four living creatures full of eyes before and behind. And the first creature was like a lion, and the second creature like a calf, and the third creature had the face of a man, and the fourth creature was like a flying eagle.

Ezekiel (1:18-19): As for their rims, they were high and dreadful and they four had their rims full of eyes round about. And when the living creatures went, the wheels went beside them; and when the living creatures were lifted up from the earth, the wheels were lifted up.

Ezekiel (10:12): And their whole body, and their backs, and their hands, and their wings, and the wheels, were full of eyes round about, even the wheels that they four had.

It is obvious that the writers of the above passages were referring to the Zodiac as it appeared about 5000 years ago when the four bright stars associated with the bull, the eagle, the lion and the man were situated at the Vernal Equinox, the Autumnal Equinox, the Winter Solstice and the Summer Solstice and, according to Chinese legends, kept watch over all the others.

THE NORTH CELESTIAL POLE IS APPROACHING THE NORTH STAR

Why does the Vernal Equinox move around the Zodiac? What causes the precession of the equinoxes? It will be sufficient to say that this shift of the positions of the constellations of the Zodiac is due to the attraction of the moon upon the equatorial bulge of the earth. If the earth were exactly spherical there would be no precession of the equinoxes.

The earth is somewhat flattened at the poles and it is revolving around the sun with its axis inclined at an angle to the plane in which it is moving. If the axis of the earth was perpendicular to this plane there would be no precession of the equinoxes. But one may ask, "Why has the earth not been pulled into this position?" Because of its rapid rotation. We have all watched a spinning top and have seen it lean quite a distance out of the vertical without falling over.

The precession of the equinoxes is due to changes in the posi-

tion of the celestial equator, which is gradually slipping around the ecliptic. As a result of the shift of the position of the equator, the north and south poles of rotation gradually change their positions in the sky, since each pole must always be exactly 90 degrees from every point on the celestial equator.

As a result of the motion of the north celestial pole among the stars no single star can be considered as the "North Star" for any considerable length of time. The star that we call Polaris is now only one and one-fourth degrees from the North Pole and is known as the North Star. In the time of Hipparchus this star was about twelve degrees from the North Pole. Twelve thousand years from now the bright blue star Vega will serve as Pole Star, as it did fourteen thousand years ago.

Although Polaris will continue to approach the celestial pole for something like one hundred years, this star will soon be forced to give up its favored position to other stars. Shakespeare obviously overlooked the precession of the equinoxes and the motion of the north pole in the sky when he wrote the following lines about Polaris:

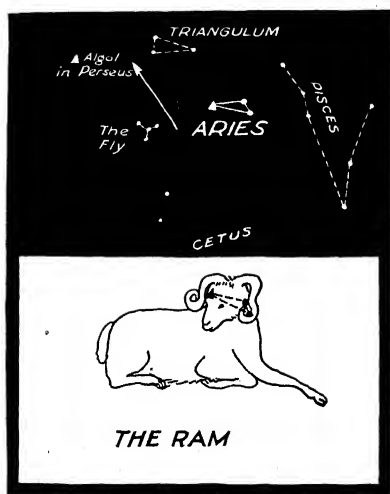
"But I am constant as the Northern star,
Of whose true, fixed, and resting quality,
There is no fellow in the firmament."

ARIES—THE RAM—IS VERY IMPORTANT YET INCONSPICUOUS

None of the constellations of the Zodiac are very conspicuous yet there is no better place to begin the Story of the Stars. Since the Zodiac is so intimately connected with the early history of the human race, everyone should be familiar with these twelve groups of stars which form the "girdle of the sky." It is always interesting to make a trip around the Zodiac and get acquainted with some of those monsters that were such a source of annoyance to the sun, as it made its annual circuit among the stars, as to give rise to the legend about the Twelve Labors of Hercules. We refer, of course, to the twelve constellations themselves and not to the twelve signs, since the latter do not remain fixed in the sky.

In order to make it easy to identify these star-groups we shall show them as they actually appear in the sky and also as they were pictured by the fertile imagination of primitive man. The imaginary tracings are plainly visible in the different figures, stars of the first magnitude being represented by a five-pointed star, those of the second magnitude by a triangle, and dimmer stars by dots of appropriate size. The drawings should be held above your head with the arrow pointing at the North Star.

Aries, the first constellation of the Zodiac, is certainly very inconspicuous, and does not in any way resemble a ram. It contains only three stars of any importance, the brightest of which is only of the second magnitude. These three stars form a small scalene triangle which early peoples always pictured in the head of the Ram. The Zodiac was probably first used by the pastoral people of Chaldea among whom the ram was such a favorite animal that its name was assigned to that constellation which served as "Leader of the Host of the Zodiac."



In early times people obtained information about the approaching seasons by noting the position of the sun among the stars. The most important time of the year for many people is the Spring Season—the word "season" comes from a word meaning "to plow"—which, as far as the northern hemisphere is concerned, begins when the sun is in Aries. Perhaps this explains why this inconspicuous constellation was selected as the first of the Zodiac. In the Old Testament and other ancient

literature there are frequent references to rams and bulls and it was very natural for primitive peoples to name the first two constellations of the Zodiac after animals that played such an important part in their religious ceremonies.

In November Aries may be seen in the eastern sky in the early evening and the little triangle will reach the meridian about 10:00 o'clock on November 23. As the constellations are, one after another, lifted up above the eastern horizon the Ram leads the parade but keeps his head turned to one side, looking back at the mighty Bull.

TAURUS—THE BULL—CONTAINS TWO FAMOUS CLUSTERS

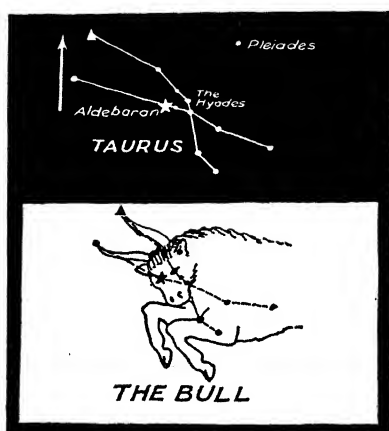
There are many reasons for believing that at the time of the invention of the Zodiac the Bull was the first, instead of the second, constellation. Does not Virgil say, "The bull with his golden horns opened the year"? In the astrological books of the Jews the bull is considered as the first zodiacal sign. Bulls were frequently sacrificed to Jupiter and the priests performed these ceremonies in the disguise of a bull-headed monster. The association of the bull with early religions is also suggested by the legend of the Rape of Europa, when Jupiter assumed the form of a bull.

We have also found proof of the fact that the Persians, Chinese and early Greeks considered Taurus to be the first sign of the Zodiac. It is said that a burial chamber has been excavated at Thebes showing a list of Signs of the Zodiac with Taurus at the head of them. On account of the precession of the equinoxes the Vernal Equinox has slowly retrograded since that time through the constellation of Taurus and then through Aries and is now to be found in the constellation of Pisces.

Taurus contains about twenty-six stars, only one of which is of the first magnitude. In this constellation will be found those two interesting clusters of stars, the Hyades which form the face of the bull, and their half sisters, the Pleiades, which regulated the earliest calendars and fixed the date of Hallowe'en.

The Hyades were the daughters of the demi-god Atlas, to

whom Jupiter entrusted the infant Bacchus. So well did they attend to their duties that Jupiter gave them a place in the sky. The Hyades are frequently called the "Rainy Sisters" and have always been associated with rainy weather. They form a V in the sky, in one end of which shines the bright red star, Aldebaran,



which forms the right eye of the Bull and looks so much like the planet Mars. The similarity between Aldebaran and Mars is only apparent, however, for Aldebaran is 40 times as large as the sun and 90 times as bright, while Mars is much smaller than the earth and borrows all of its light from the sun.

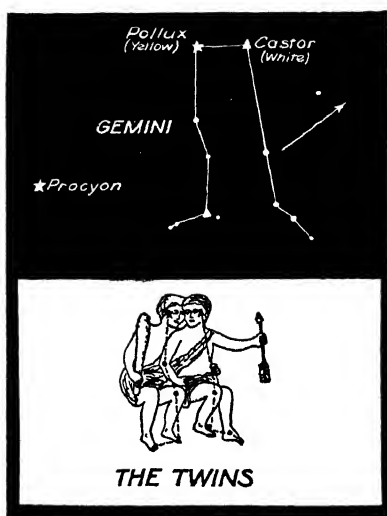
Taurus is visible in the eastern sky in early December and near the end of the month Aldebaran will cross the meridian about 16 degrees north of the equator at 10:00 o'clock.

THE TWINS—CASTOR AND POLLUX—FOLLOW TAURUS ACROSS THE SKY

The constellation Gemini—the Latin word for twins—seems to have received its name from the two bright stars, Castor and Pollux, which belong to this group. Castor and Pollux were the sons of Jupiter, Castor being mortal and Pollux immortal. One day Castor was slain in combat and Pollux, his twin brother, begged his father Jupiter to allow him to die also in order that he might not be parted from his brother. Jupiter was so touched

by this brotherly affection that he brought Castor back to life and later transferred his twin sons to the sky where they now form the bright stars in the constellation Gemini. These stars have also been called David and Jonathan.

Castor and Pollux were great favorites with the Romans who gave them credit for leading their armies to success in battle. Many feasts were held in their honor and temples were dedicated to them. Sailors were always sure of fair weather when the Twins were in the sky and sometimes named their ships after them. In Acts (28:11) St. Paul writes: "After three



months we departed in a ship of Alexandria which had wintered in the isle, whose sign was Castor and Pollux." These two stars will be found about half way between Sirius and the bowl of the Big Dipper.

Pollux is now the brighter of the two and has an orange tint, but 300 years ago Castor excelled its twin in brightness. A small telescope will break Castor into two stars but this star really consists of at least six separate stars all revolving around each other. It was in the constellation Gemini that the astronomer at Flagstaff Observatory discovered the new planet on January 21, 1930, which we hope will prove to be one of the long-sought worlds beyond Neptune. The constellation Gemini now contains the Summer Solstice, the most northerly point reached by the sun.

A few minutes' study of the eastern sky in early January will enable one to identify the Twins. They will be found to the northeast of Taurus and Orion and across the Milky Way. Near the middle of February they will be on the meridian at 10:00 o'clock about 30 degrees north of the equator. As we watch this magnificent pair of stars climb toward the meridian our imagination carries us back to those early days when Homer and Virgil sang their praises of Castor and Pollux.

THE SUN ONCE REVERSED ITS DIRECTION IN THE CONSTELLATION CANCER

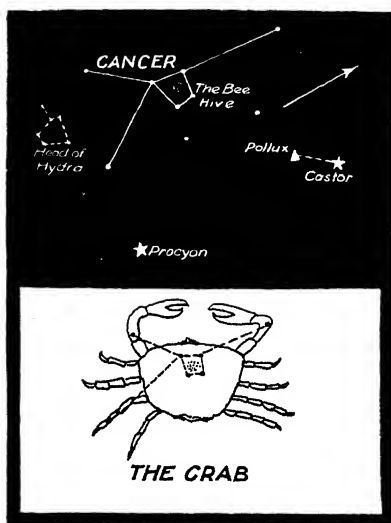
As the ancients watched the sun rise day after day they noticed that on each morning after the middle of the winter it rose farther north than it did on the morning before, and that it continued to move toward the north until about June 21 when it reversed its direction and began to move toward the south. Thus the constellation where the sun was to be found at the time it reversed its direction was very naturally named after the only creature with which the ancients were familiar that moves backward all of the time. This creature they called Cancer or the Crab. This also explains why the line on the earth that separates the Torrid Zone from the North Temperate Zone and lies directly under the sun on June 21 is called the Tropic of Cancer.

There are no bright stars in this constellation, but in its center will be seen that silvery spot called Praesepe, or the Manger, sometimes known as the Beehive in early English literature. The Beehive attracted the attention of poets from Homer down through the ages but its true character was unknown until Galileo studied it with his little telescope and announced the fact that it was made up of a mass of very small stars not visible to the naked eye.

The Crab was associated in ancient legends with early sun-worship. You may recall that immediately after the birth of Hercules the jealous Juno sent a terrible Hydra to destroy him and also sent a Crab to annoy him by pinching his heels while he was trying to defend himself against the Hydra. After Her-

cules had killed the Hydra and had crushed the Crab under his heel both were transferred to the sky where they may be seen side by side low in the east at sunset in February and directly overhead in April.

It is somewhat difficult to identify Cancer, for it contains only five dim (fourth magnitude) stars. Four of these lie almost in a



straight line north and south and may be seen on the meridian about 20 degrees north of the equator at 10:00 o'clock on March 2. Look for them midway between Pollux and Regulus. Immediately south of Cancer will be seen the small group of four stars which form the head of the Hydra. Its long body extends across the sky toward the southeast.

THE SEVEN STARS OF LEO FORM A SICKLE

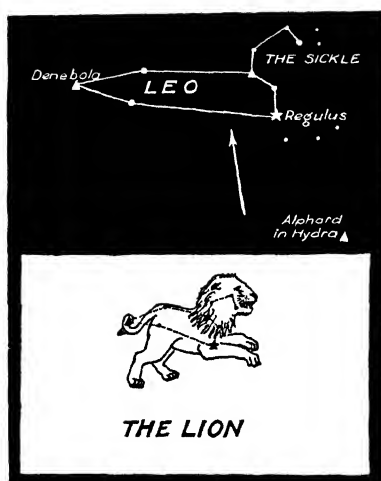
In the constellation Leo will be seen a group of seven stars forming a sickle, the brilliant Regulus being at the end of the handle. The blade of the sickle was supposed to form the head, and Regulus the heart, of the Lion. You can easily identify Leo if you look just back of the bowl of the Big Dipper.

The swarm of meteors which the earth encountered in 1833 and again in 1866 were coming from the direction of Leo. They

are moving around the sun in an elliptical orbit and appear to come from a point inside of the blade of the sickle.

Because of the precession of the equinoxes the Summer Solstice gradually slips around the Zodiac. Today it is in the constellation Gemini, yesterday (astronomically speaking) it was in Cancer, and day before yesterday (about 5000 years ago) it was in Leo. It was natural to name this constellation after the King of Beasts to symbolize the fact that when the sun was in Leo it had reached the zenith of its power and strength. Of course the eighteen stars in Leo do not have the appearance of a lion, but this was not the way the constellations got their names.

The Greeks seem to have identified this constellation with the Nemæan lion which was slain by the sun-god Hercules at the



request of King Eurystheus. In fact, it is possible to identify several of the Twelve Labors of Hercules with certain of the twelve constellations of the Zodiac. If it is true, as some people believe, that the Twelve Labors of Hercules as they have come down to us from ancient mythology are merely symbolic of the passage of the sun through the twelve signs of the Zodiac, this identification may some day be complete.

Regulus has always been a famous star. It was one of the four Royal Stars of the Chinese and Persians which marked the four cardinal points of the sky. The Arabs called it "the Kingly Star" and "The Heart of the Royal Lion." There are

nineteen stars which exceed Regulus in brightness so that the fame which it achieved fifty centuries ago was due, not to its luster, but to its position near the Summer Solstice. Watch for the white star Regulus in the eastern sky in February. It will be on the meridian about 12 degrees north of the equator at 10:00 o'clock on March 23.

VIRGO WAS NAMED FROM THE VIRGIN OF HARVEST

Without a fixed calendar primitive man depended upon the sun to inform him by its position in the Zodiac when to plow, when to sow, and when to reap. Having learned that his crop must be harvested when the sun reached a certain position among the stars, he naturally watched this star-group as each succeeding sunset found it farther toward the west, realizing that its final disappearance in the evening twilight would be a sign that harvest time was near.

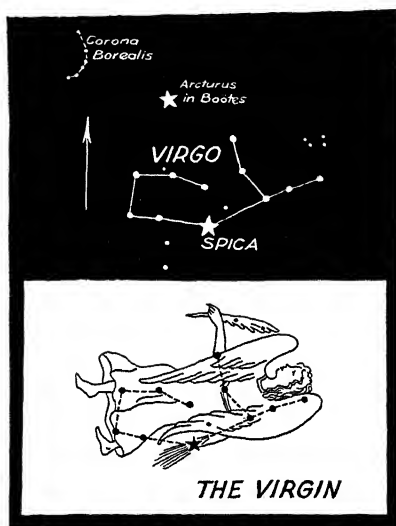
His thoughts probably turned to some of the fairy tales about the Virgin of Harvest, such as the story of Ceres and Proserpina, which were common to all early races and before long this constellation became known as the Virgin. It is probable that the Virgin was one of the first star-groups to be named for we find it in the ancient astronomical records of every race. Virgo, to use the Latin form, was usually represented by the figure of a woman with wings, holding in her left hand either a head of wheat or an ear of corn, in which is located the brilliant star Spica.

The section of the sky occupied by the fifteen stars of Virgo is of special interest from an astronomical point of view because of the large number of nebulae that have been found in this region, no less than 500 having been discovered in its eastern extremity. The Autumnal Equinox is now located in Virgo.

The brilliant white star Spica is brighter than Regulus in Leo but inferior to its neighbor Arcturus in Boötes. It has been an object of interest in all ages and has been called by many names. It is said that the Egyptians built temples oriented to this star which were so constructed that when Spica was on the

eastern horizon its light would penetrate the entire length of the temple and fall upon the sanctuary.

Virgo may be easily identified just east of Leo. Near its center is the white Spica and a few degrees to the north lies the



orange Arcturus. These two stars, together with a second magnitude star on the eastern border of Leo and a dimmer one about twenty degrees to the north, form the celebrated "Diamond of Virgo." Look for Spica in the southeast in April and May. It will cross the meridian at ten o'clock about eleven degrees south of the equator on May 12.

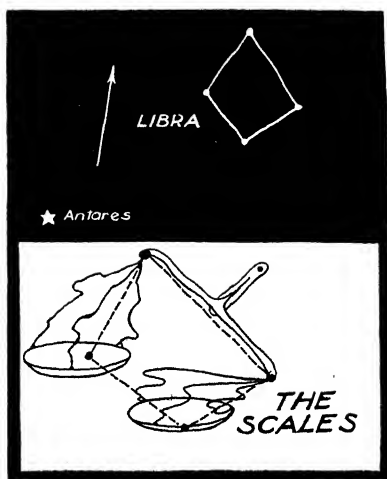
LIBRA WAS ONCE A PART OF SCORPIO

The tribes in the Valley of the Euphrates have been given credit for the invention of the Zodiac but one of these constellations, Libra, seems to have originated in another part of the country. Had they seen any necessity for detaching this small group of seven stars from the adjacent constellations they would probably have named it after some animal as in the case of the other eleven. As the Zodiac has come down to us this is the only constellation that represents an inanimate object.

For about fifteen centuries immediately preceding our era

the Autumnal Equinox was in this part of the sky so that when the sun was in this constellation the days and nights were of equal length. This was symbolized in India by the figure of a man holding in his hand a pair of scales. Among the Egyptians and the early Hebrews this constellation represented a Scale-beam and in China it was first a dragon but afterwards a celestial Balance. Thus a celestial symbol of the equality of days and nights seems to have been common to a number of early peoples.

In Greece *Libra* was not a separate constellation but was a part of *Scorpio*, the seven stars of *Libra* formed the claws of the Scorpion. During the time of Julius Cæsar the Romans imported the Balance, along with the Calendar, from Egypt and replaced the claws of the scorpion with a figure of Julius Cæsar holding a balance in his hand. Later the man disappeared leaving only the Scales as we have them today.

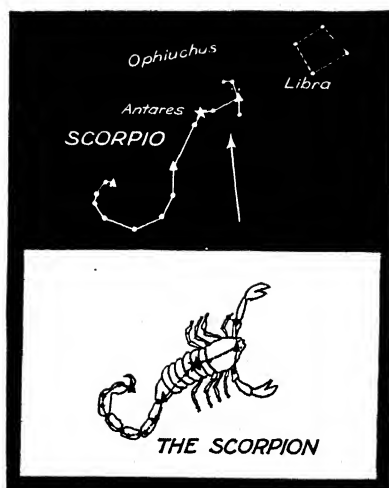


Libra may be very easily identified. It contains seven stars, none of which are brighter than the third magnitude and its principal stars form a diamond-shaped figure midway between *Spica* in *Virgo* and *Antares* in *Scorpio*. The Arabs called the star in the northern corner of the Diamond "the Northern Claw of the Scorpion"—they included all of *Libra* in *Scorpio*. This star has a greenish tint and is the only one of its type visible to the naked eye. *Eratosthenes* called this star the brightest in the *Scorpio* so that either *Antares* has increased in brightness or this star has faded considerably. *Libra* is visible in the south-

eastern sky in May and by June 5 it has drifted westward until it will be on the meridian at ten o'clock. Look for it about fifteen degrees south of the equator.

SCORPIO REALLY RESEMBLES A SCORPION

Immediately southeast of Libra and buried in the Milky Way shines Scorpio, the brightest of the twelve constellations of the Zodiac. Scorpio may be very easily identified for the row of stars in the southern part of the constellation, which some savage races call the Fishhook, has a striking resemblance to the tail of a scorpion. This is the only Zodiacal constellation which can be said to resemble the object after which it was named.



Scorpio is one of the oldest of the constellations and at one time extended westward as far as Virgo. Among most tribes it was represented by a scorpion, others preferred to see it as a snake, and still others as a crocodile. The scorpion was later robbed of his claws to form the new constellation Libra, which now separates Scorpio from Virgo.

Just above the two stars in the end of the tail of the scorpion are two beautiful star-clusters which were first studied by Sir William Herschel. This region of the sky is also famous for the

large number of "new stars" which have blazed out in Scorpio and adjacent constellations.

The brilliant red star in Scorpio is known as Antares, from two Greek words meaning "the rival of Mars." This star attracted the attention of all early races and has been called by many names. Among the Arabs it was "the Scorpion's Heart," and among the Chinese "the Fire Star." Antares was one of the four "Royal Stars" of Persia and guarded the Winter Solstice 5000 years ago. When we learn that at that time Scorpio was known to the Jews as the Eagle we can recognize one face of the Cherubim so vividly pictured by Ezekiel in his attempt to describe four constellations of the Zodiac.

When the early Egyptians were building temples oriented to Antares little did they suspect that this star was 14,000 times as bright as the sun and 90 million times as large—the largest star now known to man. Neither did they realize that the rays of light from Antares spent 300 years on the way before they penetrated the sanctuary of the temples.

Watch for Antares and the Scorpion. They rise at sunset about thirty degrees south of east early in June and remain in the evening sky until December. On June 27 Scorpio will be on the meridian at ten P. M. about twenty-six degrees south of the equator.

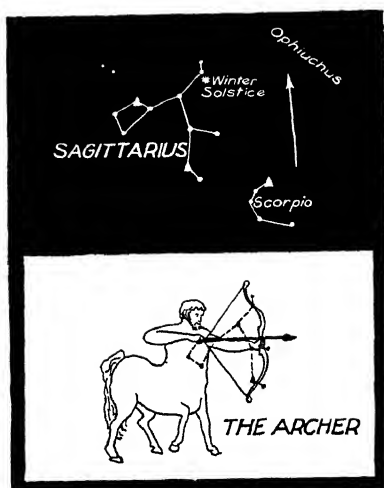
SAGITTARIUS MARKED THE POSITION OF THE SUN AT HUNTING SEASON

Just east of Scorpio lie the stars among which early peoples found the sun during the hunting season. This group was naturally called Sagittarius, or the Archer, and is one of the oldest constellations. The picture as it has come down to us from the Greeks represents the centaur Chiron, with the head of a man and the body of a horse; the son of Neptune, the god of the sea. In his hands he holds a bow and arrow aimed at the heart of the Scorpion.

In the earliest Zodiacs we do not find the man included, merely the bow and arrow and sometimes the arrow alone. The Hindus called this constellation "the Arrow" and the Arabs "the Bow."

Another name for Sagittarius was "the Bull Killer," which was probably suggested by the fact that this constellation is exactly opposite Taurus in the Zodiac so that when it rises in the east the Bull disappears in the west just as if it had been slain by the Archer.

You probably remember the classical legend about Diana and Orion and how the goddess of hunting, at the suggestion of



her twin brother Apollo, aimed the fatal arrow at this famous hunter as he was swimming in the ocean. How easily this legend might have originated from the relative positions of Sagittarius and Orion in the sky, especially since Diana was also the goddess of the Moon, which passes through Sagittarius once every month. Night after night, as Sagittarius rises above the eastern horizon and aims the bow into the sky, Orion sinks below the waves in the west.

To the modern astronomer Sagittarius is one of the most interesting parts of the sky. In this constellation have been discovered many nebulas, both bright and dark. The Winter Solstice is now in Sagittarius and here also Dr. Shapley has recently placed the center around which our sun and all the stars are revolving.

The eighteen stars of Sagittarius do not in any way resemble the picture as we have received it from the Greeks, although a string of small stars in that part of the constellation crossed by the Milky Way does bear a certain resemblance to a bow. Sagit-

tarius rises twenty degrees south of east in July and is visible until January, crossing the meridian about thirty degrees south of the equator at ten o'clock August 7.

IN CAPRICORNUS THE SUN CLIMBS LIKE A GOAT

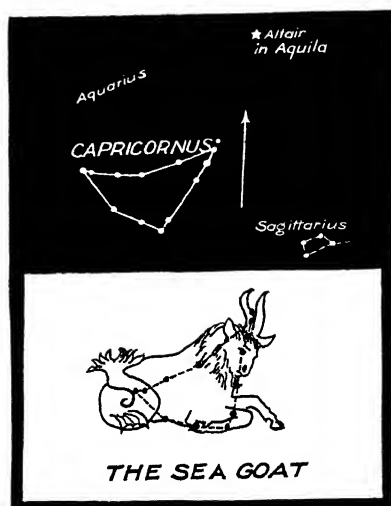
The small group of stars just east of Sagittarius has been represented in all ages and by all peoples by an animal with the body of a goat and the tail of a fish. This constellation, which is very inconspicuous and difficult to identify, is known as Capricornus, the Sea-Goat. The secret of the origin of this curious creature is hidden in the records of prehistoric times.

This constellation may have been named by the Chaldeans when the Winter Solstice was in this part of the sky, about 28,000 years ago. After mid-winter was past and the sun began its return trip toward the north they could not help but notice how it daily climbed higher and higher in the sky while passing through Capricornus. They recognized the goat as an expert at climbing and they perhaps gave it the tail of a fish to symbolize the rains of the winter season. By some ancient Oriental peoples Capricornus was called "the Southern Gate of the Sun," probably because it then contained the Winter Solstice. In Greek mythology this group of stars was known as "the Gate of the Gods" and the souls of men, after they had been released by death, were supposed to pass through this constellation on the road to heaven.

We find in classical mythology an interesting legend which seems to have been invented to account for the curious shape of Capricornus, as well as for the fact that the Greeks sometimes called this constellation Pan. One day Bacchus (often called Pan), the god of wine, was forced to jump into the Nile River to escape from the giant Typhon and that part of his body which was visible to Typhon was transformed into a goat and that under the water assumed the form of a fish. When Jupiter discovered his friend in this predicament he immediately transferred him to the sky.

It was in the constellation Capricornus that the German astronomer Galle found the new planet Neptune on September

23, 1846. Neptune requires 165 years for one trip around the sun and is now in Leo, having moved through Aquarius, Pisces, Aries, Taurus, Gemini and Cancer since its discovery.



Look for Capricornus low in the sky, about twenty degrees south of east, after sunset, in August. By September 11 it will be on the meridian at ten o'clock and it will be in the evening sky until January.

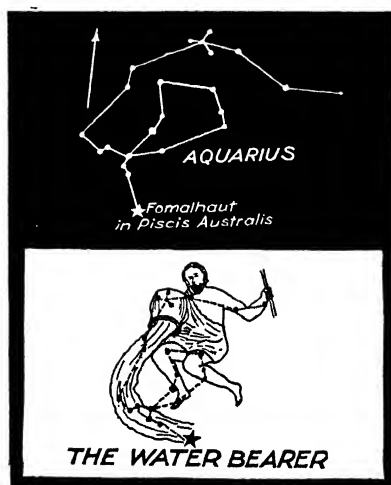
THE RAINY SEASON FINDS THE SUN IN AQUARIUS

If we should make an imaginary trip with the sun eastward around the Zodiac beginning with Aries we would spend the first nine months on land and the other three months on water. We would encounter in successive months nine objects—the Ram, the Bull, the Twins, the Crab, the Lion, the Virgin, the Scales, the Scorpion, and the Archer—which obviously belong on dry land. We would then spend a month with the Sea-Goat, whose form suggests that it lives on the dividing line between the wet and the dry parts of the Zodiac and that it may thrive either on land or in water, after which we would find ourselves in the midst of a great celestial sea in which we must spend the remainder of the year.

Immediately in front of us lies Aquarius, the Water Bearer,

pouring water into the mouth of the Southern Fish, and beyond Aquarius lies Pisces, the Fishes. As we look out over the celestial waters we recognize the Whale, the Crane, the Dolphin, the River Eridanus, and Pegasus—the winged horse that was created by Neptune and flew up out of the depths of the sea.

Surely such an arrangement could not have been accidental. The designers of the Zodiac must have carefully arranged the constellations in such a way that the sun would be in this celestial sea during the rainy season and were it not for the precession of the equinoxes, the last three (wet) constellations would forever mark this particular season of the year. Fortunately we know how fast the equinoxes are moving so that we can say that the Zodiac was invented about 28,000 years ago.

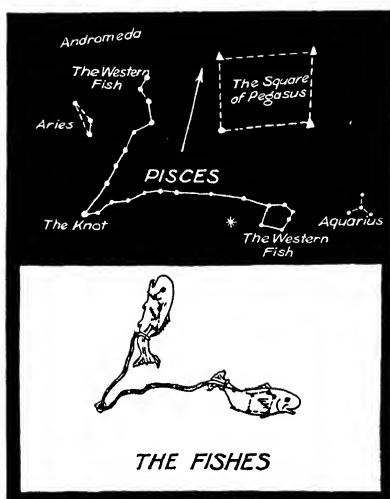


Aquarius, the eleventh constellation, was represented among all peoples except the Arabs by the figure of a man pouring water from a jar. In Arabia, where the drawing of the human figure was forbidden, the man was omitted and only the jar of water appeared.

After a little study Aquarius can be identified, although it contains no bright stars and is not very conspicuous. Look for four dim stars forming a "Y" (open toward the west) about thirty degrees north of the bright Fomalhaut. These stars represent the jar of water. Late in July Aquarius rises at sunset almost due east and remains in the evening sky until late in January. Late in September it will be on the meridian at ten o'clock.

PISCES IS THE LAST OF THE HOST OF THE ZODIAC

Before the sun emerges from the starry ocean, in which primitive man imagined it floated during the rainy season, it must spend a month in Pisces, the Fishes, the twelfth constellation of the Zodiac. Pisces is represented by two fishes quite a distance apart, one lying immediately south of the Square of Pegasus and the other much farther to the north and directly east of Pegasus. A cord is wrapped around the tail of each fish and the other ends of the cords are tied together in a knot.



The Greeks, following their custom of inventing fairy tales to account for the presence of certain animals in the sky, explained the existence of this constellation by one of their many legends. You may recall that the monster Typhon drove Pan into the Nile River where he remained until rescued by Jupiter and placed in the sky as Capricornus. This time we find Venus and her son Cupid jumping into the Euphrates River and transforming themselves into fishes in order to escape this same giant. On this occasion Jupiter seems to have been occupied with other duties and Minerva came to their rescue and transferred them to the sky.

The Vernal Equinox is now in Pisces because of the precession of the equinoxes, and this is the first, and not the last, constellation of the Zodiac. However, when the Zodiac was invented

about 28,000 years ago the Ram was the "Leader of the Host of the Zodiac" and the Fishes were the last in line. Since that time the Vernal Equinox has slipped backward completely around the Zodiac and has gotten as far as Pisces on its second circuit.

Pisces is fairly easy to identify. The Western Fish is marked by a small circle of four dim stars immediately east of the "Y" in Aquarius and south of the Square of Pegasus. The Northern Fish lies midway between the Square of Pegasus and the little triangle in Aries. Look for the two cords represented by strings of small stars running east from the Western Fish and south (slightly east) from the Northern Fish. They are joined together in a knot represented by a star of the third magnitude due south of the triangle in Aries and almost on the equator. Pisces rises at sunset almost due east in September, crosses the meridian at ten o'clock in early November and remains in the evening sky until late February.

CONSTELLATIONS OF ZODIAC WERE NAMED WHEN NEEDED

To one who has made a study of the "Girdle of the Sky" it is obvious that the constellations of the Zodiac were not all named at the same time. Just as ancient festivals were celebrated annually when the sun occupied certain positions among the stars and the other days of the year were allowed to pass unnoticed and unrecorded—they had no fixed calendar—likewise did certain groups of stars become famous because they marked the position of the sun in the sky during these important seasons and other groups remained for a while unnamed.

Our sun-worshipping ancestors celebrated their annual mid-summer sun festival when the sun reached the zenith of its glory and started on its return trip toward the south. The group of stars in the vicinity of this point—the Summer Solstice—was naturally an important one and was named the Lion for obvious reasons. By watching the sun as it moved among the stars, steadily advancing toward the Lion, they could predict in advance the date of the approaching festival.

Nature seems to have been unwilling for man to make use of

such a simple calendar and, by inventing what is now known as the "precession of the equinoxes," caused the Summer Solstice to gradually slip westward around the Zodiac so that after about 2000 years the mid-summer season came before the sun reached the Lion. Since the fixed stars could not be moved back to meet the sun, the Lion no longer marked the Summer Solstice and man was forced to give some name to another group of stars just west of Leo to mark the position of the mid-summer sun. This constellation he called the Crab, because of the sun's backward motion at that season. Hipparchus (born about 160 B.C.) is sometimes given credit for the discovery of the precession but, from the names of certain parts of the Zodiac, it is obvious that people in all ages must have been aware of this slipping of the cardinal points of the sky.

The Summer Solstice has continued to slip backward until mid-summer now occurs when the sun is in Gemini, a constellation which received its name from two bright stars known as the Twins. However, modern people need not worry because the sun is no longer in the Crab when it reverses its direction. Very few of us know where the Crab is anyway.

THE TWELVE ZODIACAL CONSTELLATIONS WERE ASSIGNED TO THE CHILDREN OF JACOB

Among the early Jews each of the constellations of the Zodiac seems to have been identified with one of the children of Jacob. This is apparent from the language used by Joseph in relating his dream. Again, when Jacob blessed each son in turn he used language which obviously refers to the constellations of the Zodiac.

When Jacob referred to Reuben as "boiling over as water," we immediately recognize the insignificant Aquarius. The oldest son probably forfeited his position as Leader of the Host of the Zodiac because of his sin against his father. Simeon and Levi, "the brethren," are the twin stars Castor and Pollux in Gemini. Judah, "the Lion's whelp," was Leo and Dan, "a serpent in the way," is obviously identified with Scorpio. Naphtali, "a hind let loose" is Capricornus and Gad is Aries, the leader of the flock. Jacob's statement, "a troupe shall press upon him; but he shall

press upon their heel" is very striking in view of the fact that the creatures of the Zodiac appear to run around the sky in a circle. They all push the Lamb from behind, but he in turn presses upon the last constellation.

Asher, who was a weigher of bread, is identified with Libra which the Hebrews represented by a Scale-beam. Issachar, "a strong ass crouching down between the sheep folds," is the Bull and Zebulon who, "shall dwell at the beach of the sea," is Pisces, a constellation on the edge of the celestial sea. To Dinah,

<i>GAD - Aries</i>	<i>ASHER - Libra</i>
<i>ISSACHAR-Taurus</i>	<i>DAN - Scorpio</i>
<i>SIMEON } - Gemini</i>	<i>JOSEPH - Sagittarius</i>
<i>LEVI }</i>	
<i>BENJAMIN-Cancer</i>	<i>NAPHTALI-Capricornus</i>
<i>JUDAH - Leo</i>	<i>REUBEN -Aquarius</i>
<i>DINAH - Virgo</i>	<i>ZEBULON-Pisces</i>

CHILDREN OF JACOB IDENTIFIED WITH ZODIAC

the only daughter, was assigned Virgo and Joseph, "his bow abodes in strength," was the Archer. To Benjamin, Jacob's youngest son, was assigned the constellation Cancer which was formed from Scorpio many years after the other eleven had been invented.

The "four Royal Stars" of the Persians were located at the four Cardinal Points of the sky in Leo, Aquarius, Taurus, and Scorpio. To the four chief tribes of Israel were assigned these same four constellations which they carried on their standards—Judah a lion, Reuben a man, Ephraim a bull, and Dan a scorpion.

At one time the theologians discarded the old pagan names for the Signs of the Zodiac and some of the older constellations and put the apostles and other New Testament characters in the sky. St. Peter replaced Aries, St. Andrew replaced Taurus, Perseus was called St. Paul, and Aquarius was called John the Baptist, Mary Magdalene replaced Cassiopeia, etc. These names, however, were soon dropped.

THE GREAT BEAR IS THE OLDEST CONSTELLATION

The twelve Zodiacal constellations, which mark the position of the sun at different seasons of the year, are intimately related to the history and the religion of prehistoric man and should be familiar to everyone. But there are many star-groups in other parts of the sky that are more conspicuous than those in the Zodiac and have some interesting stories connected with them. Perhaps the best known constellation is the Big Dipper in the northern sky which is so easily recognized.

The Big Dipper is unquestionably the oldest of all constellations and is very conspicuous in the sky. It was almost universally called the Great Bear, the word "great" being used to distinguish it from the Little Bear which is not very far away in the sky. In almost all of the records of an astronomical character that have come down to us we find references to these famous groups of northern stars, usually referred to as "the Bears." Almost everyone is familiar with these two constellations which are now known as the Big Dipper and the Little Dipper. The Big Dipper is composed of seven bright stars, four of them forming the bowl of the dipper and the other three forming the handle. It goes round and round the pole star, never going below the horizon if the observer is not too far south.

The Hindus usually referred to the seven stars in the Big Dipper as the Seven Shiners, or the Seven Wise Men. In Egypt this star-group was the Car of Osiris, in China it was the Ladle and in India it was the Seven Bears. The Arabs called this constellation the Coffin, probably referring to the slow and solemn motion of these stars around the Celestial Pole. The four stars formed the coffin and the three others were the mourners. The Christian Arabs looked upon this star-group as the Grave of Lazarus. To the early Hebrews it was a Bier, to the Syrians it was a wild Boar, and to the Druids it was Arthur's Chariot.

In France the Big Dipper was called David's Chariot and in England it was King Charles' Wain. It has also been called the Plough and Job's Coffin, but the most popular name seems to have been the Bear. We find references to this prominent con-

stellation in the works of Homer and several other Greek writers and in some of the Books of the Old Testament.

THE ARCTIC ZONE IS NAMED FOR THE BEAR

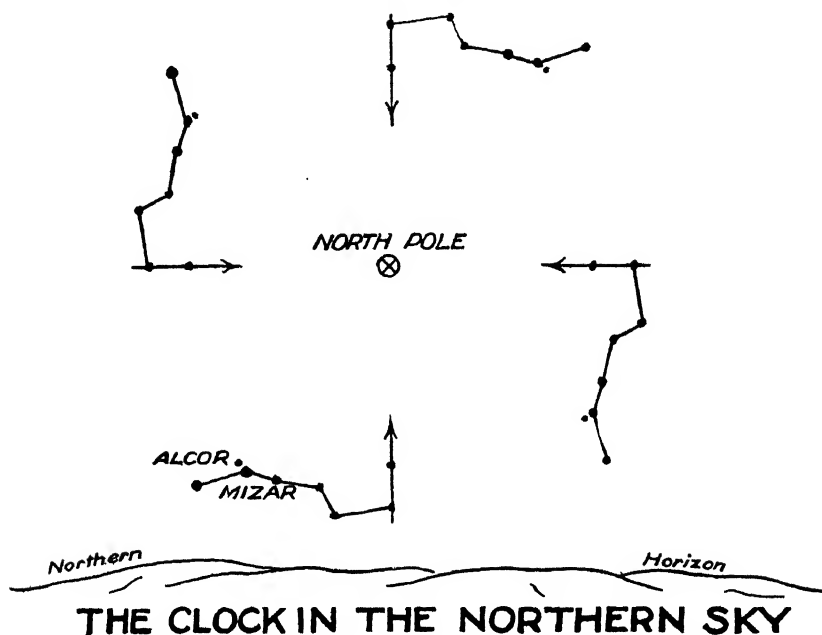
Few of us know that the Big Dipper—the Great Bear—is responsible for some of the words we use in the study of geography. The Greek word for bear is *Arctos* and when we recall that this constellation revolves about the north pole of the sky we understand why that part of the earth that lies under the north pole is called the *Arctic Zone*, and why the circle that separates this zone from the north temperate zone is called the *Arctic Circle*. Of course, the zone that is on the opposite side of the earth from the *Arctic zone* is naturally called the *Ant-arctic zone*, which means “opposite the *Arctic*.”

The Great Bear moves slowly around the pole star in a counter-clockwise direction, making one complete circuit in twenty-four hours. Here is a celestial clock that never runs down, requires no attention and is always absolutely accurate. From this natural clock the expert astronomer can get his time with an error of only a few minutes if he knows the day of the month. When the Dipper is below the pole star it is in its natural position. Six hours later it will be standing on the end of its handle on the east side of the pole. At the end of twelve hours it will be upside down and over the pole and at the end of eighteen hours it will be found west of the pole and standing on its bowl. Watch for the Dipper in the evening twilight when the stars first begin to appear. You will find it directly over the pole in May, west of the pole in August, directly beneath the pole in December and east of the pole in late February.

The Greek poet Homer referred to this constellation when he mentioned the “bear that never bathes in the ocean.” Incidentally this tells us something about the latitude in which Homer lived, for this constellation would not have remained above the horizon unless he had lived north of a certain parallel of latitude.

Almost every reference to an astronomical phenomenon in the works of the authors of antiquity furnishes some information with reference to the locality in which the writer lived. For

example, in the "Book of Zoroaster" we find the statement that the length of a summer's day is twice that of a winter's day. This is true only in latitude forty-nine degrees.



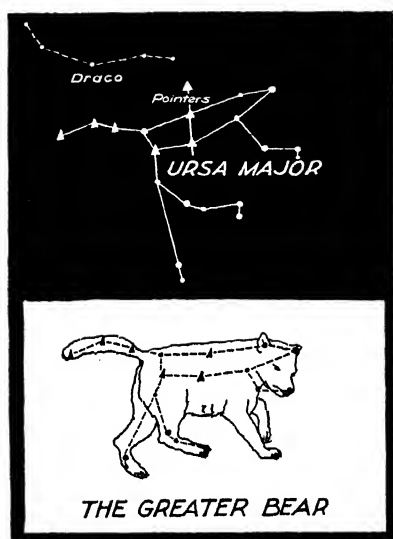
THE "TEST STAR" IS IN THE TAIL OF THE GREAT BEAR

The middle star in the handle of the Dipper furnishes an excellent test of your vision. Look at this star very closely and see if you cannot see a small companion star close to it. If you can, then your eyesight is up to normal. This is a beautiful double star but some people can see it only as a single star. It is interesting to note that when a large telescope is turned on this star and its companion they break up into six individual stars. The Arabs called the bright star Mizar and their name for its dim companion was Alcor, a word which means "the test," because this star was used as a test of vision.

Although Mizar and Alcor appear so close together that some eyes cannot separate them their distance apart is really about 15,000 times as far as from the sun to the earth. As we study the

two stars we should keep in mind the fact that we see them as they were seventy-five years ago because of their great distance from the earth.

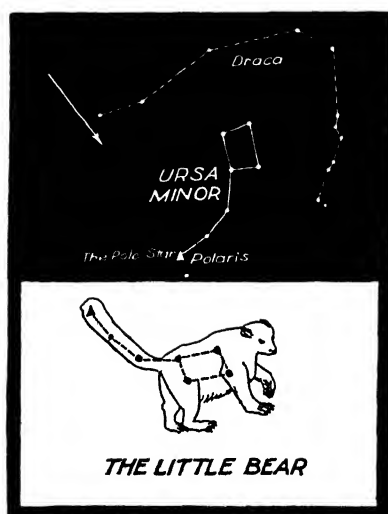
The two stars that form the outer edge of the bowl of the Big Dipper are known as the "Pointers," because a straight line through these stars always points at the North Star. In fact, this is one of the best methods of locating that important star which is sometimes called Polaris, because the polar axis of the earth, when extended indefinitely, pierces the sky very near this star.



The arrangement of the stars in the Great Bear does not in any way resemble a bear or any other animal. However, from the very dawn of civilization this constellation has been called a Bear. It went by that name in Asia, in the far north, in Egypt, Greece and Rome and, after the discovery of America, we found the American Indians calling this same group of stars "the Bear and the Hunters." These Indians were very well acquainted with bears and refused to picture this animal with a long tail as the races in the eastern hemisphere had done. To them the three stars in the handle of the Dipper represented the three hunters. If this constellation in any way resembled a bear there would be nothing remarkable about this fact, but under the circumstances we are forced to ask the question, Why is this group of stars called a bear?

JUPITER PLACED THE BEAR AND HER CUB IN THE SKY

Associated with the Big Dipper is another group of stars known as the Little Dipper, with the pole star in the end of the handle. When the Big Dipper is under the pole the Little Dipper extends westward from the pole and is upside down. Of course, twelve hours later the Big Dipper is above the pole upside down and the Little Dipper is under it and right side up. The Greeks referred to these constellations together as the Big Bear and the



Little Bear and had an interesting legend to account for their existence in the sky. Since these groups of stars were called the Bears by people in many other parts of the world, this legend was probably a part of the folklore of many of the early races.

You will recall that Jupiter, the king of the gods, frequently engaged in love affairs with mortal maidens. One day he fell in love with Callisto, the beautiful daughter of the King of Arcadia. His wife, Juno, soon discovered the object of his love and transformed Callisto and her little son into rough and ungainly bears and then drove them out into the forest. Jupiter searched for Callisto far and wide and finally recognized her and her offspring as they were wandering through the woods in search of food. He became very sorry for what he had done and transferred Callisto

and their son to the sky where they became beautiful constellations. In order that Callisto might no longer annoy her, Juno decreed that these two constellations should revolve round and round the north pole and never go below the horizon in order that she might keep her eyes on them. Juno's decree seems to have been carried out for the two Bears can be seen every night in the year and all night long.

The two Bears were used as a guide by early navigators. If one is familiar with their relation to the pole star he can always tell his direction at night. The Phoenician sailors called the Big Dipper "Doube," a word which meant the "speaking constellation." It is interesting to note that in their language this same word meant a "bear."

Look for the Little Dipper west of the pole at sunset in November, under the pole in early February, east of the pole in early May and directly above the pole in July.

A DRAGON IN THE TOP OF THE SKY GUARDS THE STARS

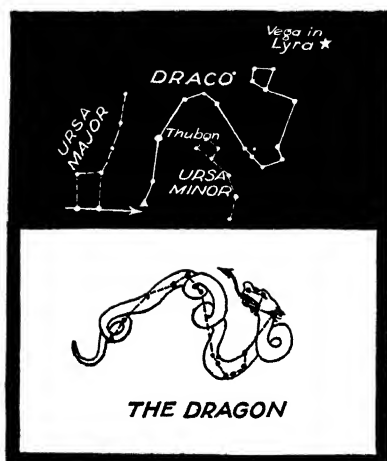
One of the earliest constellations is Draco, the Dragon, whose sixteen stars form the body of a hideous monster which primitive man placed in the "top of the sky" to guard the stars. According to a Greek legend Draco represents the dragon that guarded the Golden Apples (stars) of Hesperides (the west). This dragon was finally killed by Hercules and was placed in the sky in a position where it would never set and would always remain on guard. Next to Draco is Hercules with his foot on the dragon's head.

The dragon was known in Egypt as Typhon. It was this terrible monster that caused Pan to jump into the Nile River and also made it necessary for Venus and her son Cupid to take refuge in the Euphrates to escape with their lives. Fortunately they were all rescued and transferred to the sky where they now form the constellations Capricornus and Pisces.

The brightest star in Draco was known to the Arabs as Thurban. Because of the precession of the equinoxes the celestial pole moves among the stars. About 14,000 years ago it was near

Vega and this same star will be the North Star again in 12,000 years. About 4700 years ago Thuban was the North Star. Not only was the Great Pyramid in Egypt laid out exactly north and south but it was so oriented that the light from Thuban shone directly down its central passage in 2170 B. C. Perhaps it was built at that time and this passage was pointed directly at the North Star.

One cannot look at Draco with its coils wrapped around the star that was at the north pole several thousand years ago with-



out recalling the Hindu legend about the snake that was wrapped seven times around the axis of the earth and which the gods and demons pulled back and forth by its head and tail, thus causing the earth to spin on its axis.

Draco may be easily identified. Its diamond-shaped head lies not far from the bright blue Vega and may be seen above the pole at ten o'clock near the end of July. Its body extends first in the direction of the North Star then bends back between its head and the bowl of the Little Dipper, its tail then passing between the Little Dipper and the Big Dipper and ending near the bowl of the latter.

PERSEUS SLEW MEDUSA

There is a group of constellations in the northern sky around which the Greeks constructed the beautiful legend of the rescue

of Andromeda. These are Perseus, Andromeda, Pegasus, Cassiopeia and Cepheus.

Perseus was a sun-god like Hercules. His father was Jupiter, the king of the gods, and his mother was a mortal princess by the name of Danaë. Perseus, like Hercules, was given many difficult tasks to perform, one of which was to kill the hideous Medusa. At one time Medusa was considered to be a very beautiful woman but she became angry at Minerva and boasted that she, Medusa, was much more beautiful than the goddess of wisdom. Minerva naturally became very angry and transformed Medusa into the



ugliest person in existence. She changed her beautiful curling locks into hissing, writhing serpents, and decreed that any person who looked into the face of Medusa should be immediately turned into stone.

To Perseus was assigned the very difficult task of getting rid of Medusa. It is obvious that she was very dangerous since one look from her meant death to any mortal. Leaving out the details as to how Perseus, with the assistance of Pluto, Mercury and Minerva, managed to get the best of Medusa, it will be sufficient to say that he finally killed her and, having cut off her head, he started flying through the air with the head of Medusa in his hand, a flight which was made possible by the use of the winged sandals of Mercury, that he had borrowed for this occasion.

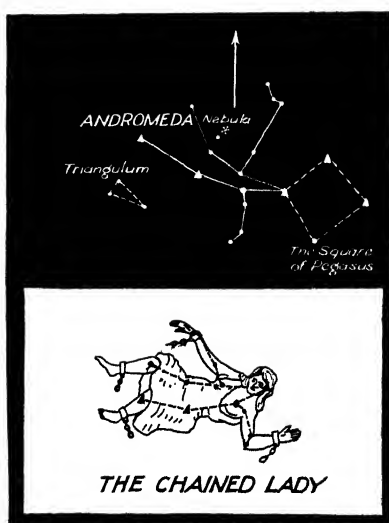
On the early star maps Perseus, the Champion, was represented with a dagger in his right hand and in his left the head of

Medusa, which contains Algol, the famous "Demon Star," so named because its light goes almost out and then comes on again every three days. The Arabs called this constellation the "Bearer of the Demon's Head." In Perseus are two famous star-clusters and among the stars of this constellation a Nova appeared in 1901 whose brightness increased 25,000 times in three days—the most brilliant new star since 1604.

Perseus rises at sunset about fifty-five degrees north of east near the middle of October and is visible in the evening sky until late in May. Algol is on the meridian at ten o'clock about the eleventh of December. Look for it about thirty degrees west of the yellow Capella.

ANDROMEDA WAS RESCUED BY PERSEUS

Between Pegasus and Perseus is a section of the sky containing about sixteen stars which the people of remote antiquity represented by the figure of a woman in a reclining position with chains



on her ankles and wrists. This is Andromeda, the Chained Lady. Andromeda was the daughter of King Cepheus and Queen Cassiopeia and the story of her rescue by Perseus has come down to us in one of the Greek myths.

One day Cassiopeia boasted that she was more beautiful than the sea nymphs, whereupon Neptune became very angry and sent a dragon to ravage the sea coast. Cassiopeia appealed to Jupiter and learned that her daughter must be sacrificed to the dragon in order to appease the anger of the god of the sea.

Perseus, who had just returned from his triumph over Medusa, looked into the northern land, recognized the charming princess, Andromeda chained to a rock and near her the terrible dragon beating the waves into a white foam with his tail. Our hero immediately sprang upon the Winged Horse and flew into the north just as fast as he could go. As he went to the rescue of the princess he raised quite a stream of dust, which we now call the Milky Way, but which the ancients said was merely the dust kicked up by the Winged Horse as he carried Perseus on his rapid flight into the north. Perseus quickly reached Andromeda and turned the dragon into stone by exposing it to a view of the face of Medusa.

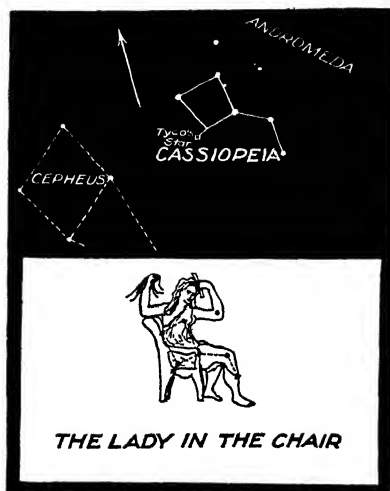
In Andromeda is the famous spiral nebula which has been known for at least ten centuries, the only one of its kind visible to the naked eye. Modern researches have shown that this nebula is really another universe at a distance of 900,000 light years, the most remote object visible to the naked eye. From this direction come the November meteors known as the Andromedes, which furnished us such a wonderful display in 1872 and 1885.

Andromeda is very beautiful as it rises in the northeast soon after sunset in late September. The star in the northeast corner of the Square of Pegasus represents her head, from which hang two chains of stars. The Chained Lady remains visible in the evening sky until late in April and will be found on the meridian almost directly overhead at ten o'clock on the eighth of November.

KING CEPHEUS AND QUEEN CASSIOPEIA RULE THE NORTHERN SKY

Just north of Andromeda lies Cassiopeia, the Lady in the Chair, and immediately west of her is Cepheus, the King. These two constellations were very closely associated in the legend of

Perseus and Andromeda, which probably explains their location in this part of the sky. Although Cepheus is very inconspicuous, Cassiopeia contains a group of bright stars which have always attracted attention. Perhaps the best way to identify this constellation is to look for a capital "M" when it is below the North Star and for a "W" when it is above, for this Queen is forced to stand upon her head daily because she once boasted that she was more beautiful than the sea nymphs.



One sometimes hears the question, "How did the stars get their names?" If we are familiar with the beautiful legends of classical mythology, the answer is obvious. A large area in the northern sky is completely filled by "the Royal Family"—King Cepheus, Queen Cassiopeia, Princess Andromeda and Perseus—whose names have been handed down by word of mouth in the story of Perseus and Andromeda for hundreds of generations. These people had no way of preserving their stories in books as we do, so they wrote this legend indelibly in the sky by placing in the heavens the four constellations of the Royal Family with the Winged Horse and the Sea Monster where they will shine forever.

It was in the constellation Cassiopeia that "Tycho's star" blazed out in November, 1572. This star which was brighter than Venus and visible in the day time gradually faded and disappeared entirely in about a year. Although this temporary star carries the name of Tycho it was not discovered by him. It

attracted his attention and he wrote an account of it later. This star was also called "the New Venus" and "the Guest Star."

Cepheus is very difficult to identify, but Cassiopeia presents a striking appearance as it circles the pole immediately behind Cepheus. It lies in the Milky Way on the opposite side of the pole from the Big Dipper and at about the same distance. Look for it overhead at sunset early in November, directly under the pole in June, east of the pole in August, and west of the pole in March. As it slowly circles the north pole Cassiopeia makes an excellent celestial clock from which the astronomer can determine the time of day with remarkable accuracy.

AURIGA CONTAINS THE GUARDIAN OF THE PLEIADES

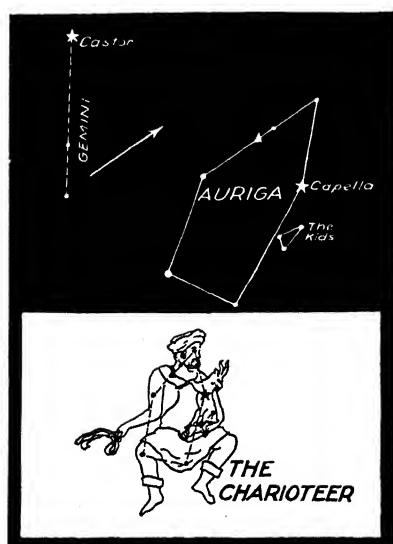
North of Taurus in the Milky Way is a group of eleven stars which has for ages been represented by a shepherd carrying a goat on his shoulder and holding two little kids in his left hand. This star-group is now known as Auriga, the Charioteer. It probably originated in the Euphrates valley for we have records which show that these pastoral people were well acquainted with this constellation at least ten thousand years ago. The name "Charioteer" may have been assigned to it because of the proximity of the Great Bear which some early peoples called a "Chariot."

In the heart of the goat shines a first magnitude star, Capella, the third brightest star visible from any point on the earth north of latitude forty degrees. Only Sirius and Vega exceed it in brightness. Capella lies in the Milky Way between Orion and the North Star and can be easily identified because of its brightness.

Capella has always been a famous star and has attracted attention in all ages. At the present time it has the distinction of lying nearer the north pole of the heavens than any other first magnitude star. From an inscription on a tablet at least 4000 years old we learn that the relative position of this star with reference to the moon on a certain day of the year served to regulate the calendar. Capella must have been intimately connected with Egyptian star-worship for several temples oriented

to that star have recently been discovered. Among the early Arabs it was known as "the Driver" and sometimes as "the Guardian of the Pleiades," which lie a little to the south and west. The Hindus worshipped Capella as the Heart of Brahma and the English poets called it "the Shepherd's Star."

Like Arcturus and Fomalhaut, Capella has a yellow tint that is immediately apparent when the light from this star is com-



pared with that from Rigel in Orion about fifty degrees to the south. Although Capella is about two hundred times as bright as the sun it has about the same temperature (6000 degrees).

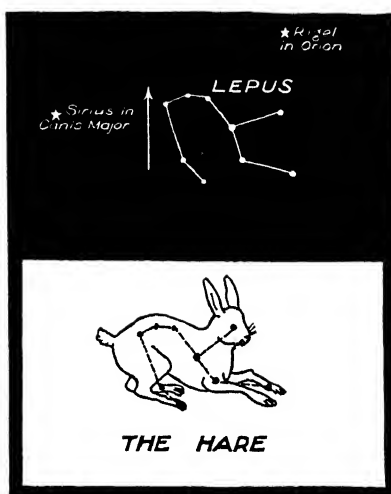
Capella rises at sunset in the northeast late in November and is in the evening sky until late in June. Watch for it near the meridian at ten o'clock early in January. Can you identify the kids? Look for three small stars close together and just a little southwest of Capella.

THE HARE RUNS FROM THE HOUNDS

Night after night primitive man watched the great hunter Orion chase the Bull across the winter sky with his two faithful dogs at his heels. But the picture was not complete until something was added to occupy the attention of the dogs and prevent

them from giving up this apparently endless chase, and so he picked out a group of stars immediately in front (west) of the Big Dog and pictured them as a rabbit. This constellation appears on the early star maps as *Lepus*—the Hare.

Here is direct evidence that the constellations were not selected at random but the entire map of starland was deliberately planned. Just as a single sentence in the Bible, or in any other piece of literature, may appear meaningless when taken out of its proper setting, so also is it rather difficult to appreciate the cor-



respondence between the name of a constellation and its picture in the sky until we take into consideration other near-by groups of stars. The picture of Hercules is not complete until we see the Dragon under his feet; the asterism known as Perseus is meaningless until we discover Andromeda, Cassiopeia, Cepheus and the Winged Horse near him; the Hunting Dogs would not be in the sky unless they were needed by the Herdsman to chase the Big Bear around the north pole; the Archer aims his arrow at the heart of the Scorpion and the timid Hare manages to keep out of reach of the Hounds of Orion.

Without the means of preserving his myths and legends in books and pamphlets, early man turned to nature for assistance and with the silver fire of the stars wrote the stories of his heroic deeds against the dark background of the sky, where they would be read by subsequent generations. For a few stories single constellations were sufficient, but in most cases a group of asterisms

was necessary and these were carefully arranged according to a definite plan.

The Hare appears on most ancient star maps and the Greek poet Aratus points it out very clearly when he says, "Under Orion's feet, mark too the Hare, perpetually pursued. Behind him Sirius drives as in chase." Since this constellation is close beneath Orion, the Arabs sometimes referred to it as "the Chair of the Giant." The Hare may be easily identified low in the south during the winter season.

THE HUNTER ORION RIDES THE WINTER SKY

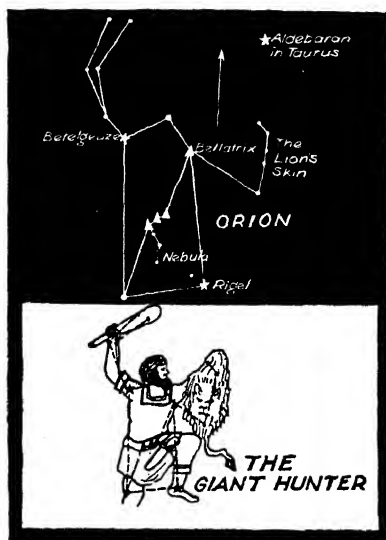
One of the oldest—as well as the most beautiful—constellations in the sky is Orion, the heavenly warrior whose brilliant stars adorn the winter sky—a constellation that was mentioned many times by the Greek poets Homer and Hesiod and also in the Book of Job. There are, perhaps, more myths and legends connected with Orion than with any other group of stars in the sky and, with the possible exception of the Dipper, the Belt of Orion is the best known of all stellar objects.

Orion was a great hunter; in fact he is supposed to have been the foremost hunter of his time. The goddess Diana, in addition to her duties as goddess of the moon, was also the goddess of hunting and she naturally became acquainted with Orion. As a result of their companionship Orion fell desperately in love with Diana and immediately aroused the anger of her twin brother Apollo, the god of the sun, from whose all-seeing eyes nothing could escape.

Apollo determined to put an end to this courtship and looked about for some way of getting rid of Orion. One day he discovered the hunter walking in the ocean with only his head above the waves. Calling Diana to his side he suggested, as a test of her marksmanship, that she try to hit that dark spot floating on the sea. Since the moon does not shine as brightly as the sun, Diana was not able to distinguish objects as clearly as Apollo and she aimed an arrow at her lover, never dreaming that it was Orion at whom she was asked to shoot. Diana's arrow found its mark, and Orion sank below the waves. Realizing what she had done,

she then transported him to the sky where he now forms a brilliant constellation.

Of course the constellation Orion does not resemble a man but all early star maps represent this group of stars by the figure of a



man with a club in his right hand with which he is preparing to strike the Bull (Taurus). Three bright stars form his belt. In his left foot is the bright star Rigel, and in his right shoulder the red star Betelgeuse:

Orion rises due east at sunset late in December and adorns the evening sky until early in June. It will be on the meridian at ten o'clock early in January.

ORION CHASES THE PLEIADES ACROSS THE SKY

Near Orion in the constellation Taurus lie the Pleiades, that little group of stars whose position in the sky determines the date of Hallowe'en. As usual, classical mythology gives us an interesting story about these two prominent star-groups.

One day as Orion was on one of his hunting expeditions he met the seven nymphs of Diana, known as the Pleiades. These nymphs were the daughters of Atlas, the demi-god who supported the heavens on his shoulders, and were noted far and wide

for their beauty. Orion naturally fell in love with them and was anxious to form their acquaintance. The Pleiades were very timid and when Orion approached and attempted to speak they turned and fled. In order that he might not lose sight of them he pursued them through the forest and was just about to overtake them when they called upon Diana for assistance and were transformed into seven snow-white doves and flew up into the sky. They were then changed into the little group of stars which we now call the Pleiades and which form a part of the constellation Taurus.

As a matter of fact there are only six stars in the Pleiades but this made no difference to early peoples. The mystic number seven was very important in those days and it would have spoiled the story to have had only six beautiful maidens. Consequently the ancients invented another story to explain why one of the Pleiades later disappeared.

The pursuit of the Pleiades by Orion has become a perpetual one. These stars move slowly across the sky every evening with Orion in close pursuit, but his efforts to overtake them seem to be in vain.

As we watch Orion chase the Pleiades across the sky we cannot fail to be impressed by the beauty of the stars in that part of the sky. At nine P. M. in late January the brilliant Orion may be seen near the meridian. Just across the meridian are the Pleiades in headlong flight followed by Aldebaran in the end of the "V" in Taurus. South of Orion's Belt lies Rigel and on the opposite side Betelgeuse. Following Orion are Sirius, Procyon and Pollux and farther to the north about halfway between Orion's Belt and the North Star the brilliant Capella rides the Milky Way. What a contrast in color these bright stars present!

THE GIRAFFE CIRCLES THE POLE

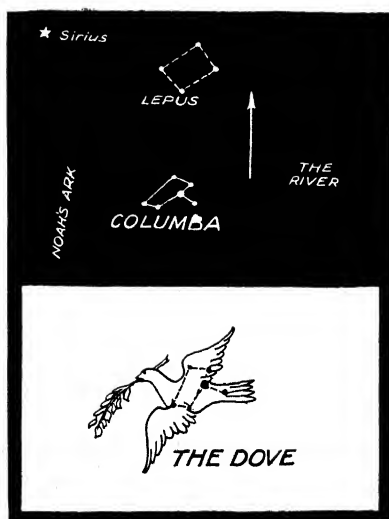
Between Auriga and the north celestial pole lies a region in the heavens that contains no stars brighter than the fourth magnitude and was consequently of no value to primitive man when he undertook the task of writing his legends and fairy tales in the open book of the sky. In this large area are no tracings, nor fanciful figures of any kind, which would attract the attention of even

the most interested observer, and so it seemed hardly necessary to give it a name. But Hevelius of Danzig insisted upon having a name for every section of starland and, in his catalogue which was published in 1690, this region is called *Camelopardalus*, meaning "the Giraffe."

There is nothing of interest in this part of the sky, but one who wishes to be able to recognize all the constellations should learn to identify the Giraffe. It is on the opposite side of the North Star from the Dragon and lies between the yellow first magnitude star *Capella* and the pole. Look for it on the meridian at ten o'clock early in January.

THE DOVE FLIES TOWARD THE ARK

The seven stars of the third and fourth magnitude lying immediately south of the Big Dog and the Hare form a constella-

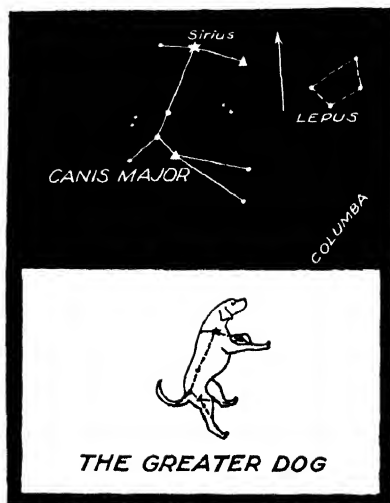


tion known as *Columba Noe*—Noah's Dove—which seems to have originated during the seventeenth century. This asterism is only a few degrees west of the constellation known as Noah's Ark and was pictured as a dove flying toward the Ark with a green twig in its mouth. Surely the constellations were not named and arranged by chance.

For convenience that part of the name referring to Noah is usually dropped and the constellation is known as Columba, or the Dove. In our latitude it never gets very high in the sky and, being made up of dim stars, it is rather difficult to identify. Perhaps the best time to look for the Dove is when Betelgeuse in Orion is near the meridian. Beginning with this red star, look southward down the meridian about forty degrees and there, just below the Hare and almost on the southern horizon, will be found the Dove. It will be in this position at ten o'clock in the evening about the middle of January.

A FAITHFUL DOG FOLLOWS THE HUNTER ORION

Every hunter must have a dog. Consequently the little group of stars which follows Orion across the sky was named the



Greater Dog, the adjective being necessary to distinguish this dog from another one near by. On the early star maps we find the Greater Dog in the act of springing at the Rabbit which is almost under Orion's feet. Although Homer and Hesiod connect this star-group with the hunter Orion, it was also called a Dog by earlier peoples who were probably not acquainted with these classical myths.

In the mouth of the Greater Dog is Sirius, "The Dog Star," the brightest and perhaps the best known star in the sky. Being visible from both the northern and the southern hemispheres this "King of Suns" has been revered and admired in all ages by all peoples. Sirius was worshipped by the early Egyptians and was intimately connected with their calendar. In Egypt New Year's Day was always celebrated when Sirius rose at the same time with the sun. At this season the Nile River always rises and overflows its banks so that the Egyptians called this star Anubis, "the Watch Dog of the Nile."

Sirius is the most brilliant star in the entire sky, not because it actually exceeds the others in brightness—some stars are a thousand times as bright—but rather because it is one of our near neighbors. It is only twenty-seven times as bright as the sun but it is so close to us that its light reaches us after spending only 9 years on the way. Sirius is a white star but it may have changed its color since early times for Ptolemy referred to it as being fiery red and Seneca said that it was redder than Mars. At any rate it is one of the hottest stars we know. Its temperature is about 10,000 degrees while that of the sun is only 6000.

When primitive peoples were dedicating temples to Sirius and worshipping it under the name of "Sothis" and "Sihor"—and many others—little did they suspect that this brilliant object was really a double star with a dark companion that is made of the heaviest material known to man.

Sirius rises at sunset late in January about twenty degrees south of east and remains in the evening sky until the middle of June. It is on the meridian at ten o'clock early in February.

ORION REALLY HAD TWO DOGS

Early peoples had so much respect and reverence for the great hunter Orion that they were unwilling to look upon him as an ordinary sportsman riding the starry paths of the sky. His fame was such that he really deserved another dog besides Sirius. They selected two stars of the first and third magnitudes directly behind the hunter and on the opposite sides of the Milky Way as a frame upon which to hang the picture of another faithful dog.

This constellation is known as the Lesser Dog and the poets of antiquity sang many songs about the heroic deeds of Orion as he rode the winter sky accompanied by his two faithful dogs.

Perhaps the most important event of the year in Egypt was the Inundation of the Nile which always occurred when the Dog Star, Sirius, rose immediately before the sun. The bright star in the Lesser Dog rises a little ahead of Sirius so that the appearance of this star warned them that this season of the year was rapidly approaching. Their name for this star was "Procyon," which means "before the dog." Thus the Egyptians looked upon Sirius and Procyon as reliable watch dogs—of which they made practical use—rather than as the hunting dogs of Orion. Here is



an example of a constellation composed of only two stars so that it could not possibly resemble the watch dog after which it was named. It was probably invented by the Egyptians for a definite purpose.

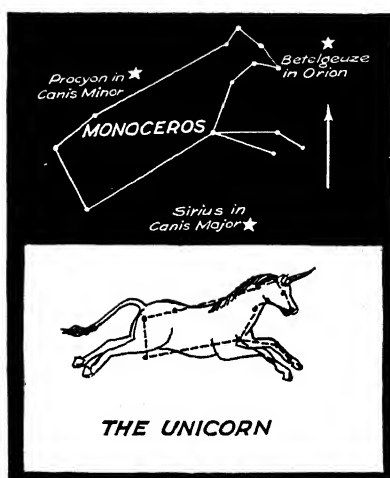
The ancients seem to have associated with the two Dog Stars, Sirius and Procyon, the idea of scorching heat. Their hottest season always came when the sun was in this part of the sky, for they were then subjected to the piercing rays of the Dog Stars in addition to those of the Star of Day. We still have our "Dog Days" at that season of the year.

Procyon may be easily identified. Look for it east of Betel-

geuse and midway between Sirius and the twin stars, Castor and Pollux. It is somewhat hotter than the sun but less than six times as bright. Its distance from the earth is about ten light years. Late in January Procyon rises at sunset slightly north of east and remains in the evening sky until early in July. It will be on the meridian south of Castor and Pollux at ten o'clock on the fourteenth of February.

THE UNICORN PURSUES THE HUNTER

That region of the sky immediately east of Orion and lying between the two Dogs is known as Monoceros—the Unicorn.



Most of this area is buried in the Milky Way but if one examines carefully that part of the "Circle of the Galaxy" between Sirius and Procyon, and at the same time makes a liberal use of his imagination, he will be able to see that curious asterism of about fifteen very dim stars which some map-maker in the sixteenth century pictured as a unicorn in the act of attacking the great Hunter from the rear.

The Unicorn is very inconspicuous but it may be identified without much difficulty during the clear winter evenings. Look for its head almost halfway between Betelgeuze and Procyon. At ten o'clock in the evening early in February, when the Seven Nymphs

of Diana—the Pleiades—are about to reach the western horizon in their flight across the sky followed by the Hunter and his two dogs, the Unicorn may be seen galloping across the meridian and vainly attempting to slay Orion before he reaches his prey.

THE LYNX IS HIDDEN FROM VIEW

In the northern sky between Auriga and the Great Bear lies a region of the heavens that was not used by the ancients to form either of these constellations. This area had no name on the early maps of the sky for it contains only very dim stars and consequently attracted no attention until the seventeenth century when it became the fashion to divide all of the visible heavens into constellations in such a way that every star would be included in one, and only one, named star-group.

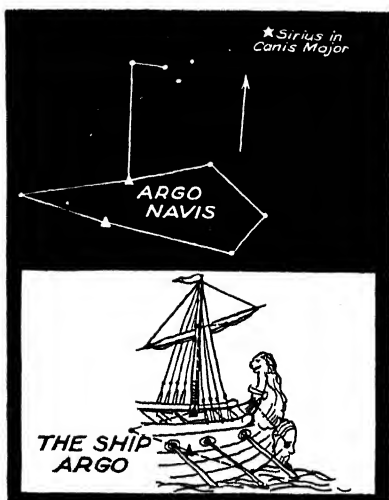
When the Celestial Chart of Hevelius appeared in 1690 this part of starland was labeled “the Lynx,” and since then it has continued to bear that name. It is next to impossible to identify the Lynx, even though we had the keen eyesight that is usually attributed to that animal, for the stars in this region are so very dim and there are no imaginary tracings such as we use to discern the more conspicuous constellations. The Lynx is on the meridian high in the sky at ten o'clock in the evening about the middle of February.

NOAH'S ARK FLOATS IN THE SKY

In the southern hemisphere, east of the Big Dog and south of the Unicorn and the Hydra, lies a constellation which from ancient times has been known as the Ship. Only the northern part of this asterism is ever visible above the southern horizon in these latitudes. This probably explains why it was always pictured without a prow, for unless the designers lived as far south as Arabia and India they could never have seen the entire ship. On modern star maps the Ship appears as two constellations, Puppis—the Ship's Stern—and Carina—the Ship's Keel.

In classical literature this star-group is known as the Ship Argo, or sometimes as Argo, and represents the famous ship in which the mythical hero Jason sailed with the Argonauts in search of the Golden Fleece. We are, therefore, not surprised to find it in the sky where, according to the ancient poet Aratus, "against the tail of the Great Dog is dragged sternward the Argo."

To the Arabs this constellation represented a ship; the Egyptians looked upon it as the Ark that carried Isis and Osiris safely through the flood water, and the Hebrews pictured it as



Noah's Ark which, in their legends, played such an important part in the preservation of the human race at the time of the Deluge.

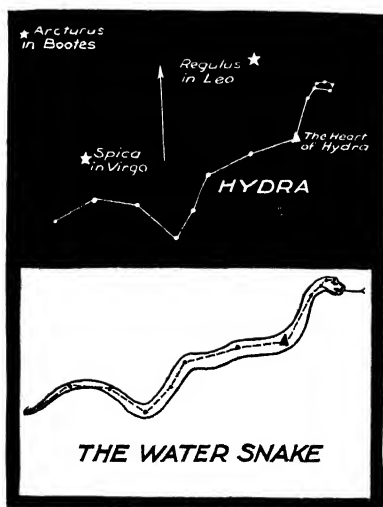
Here again is more evidence that the constellations were grouped according to a prearranged plan and were not placed in the sky at random. Not only do we find Noah's Ark in the southern heavens, but near by are the two birds released by Noah from the Ark—the Dove and the Raven—and not far away is Ara—the Altar—where sacrifices were performed after the Deluge, and from which the smoke is rising to form the Milky Way.

The brightest star in the Ship is Canopus, which is so near the south celestial pole that those of us who live north of Florida never have an opportunity to see it. This brilliant southern star

circles the south pole of starland without ever showing itself above our southern horizon, just as the Little Bear glides silently around the north pole but never disappears below the horizon. Only the Dog Star—Sirius—exceeds Canopus in brightness. Look for the stern of the Ship on the meridian low in the south and southeast of Sirius at ten o'clock in the evening near the middle of February.

THE WATER SNAKE IS STRIKING AT THE LITTLE DOG

On the early star maps the long string of about fifteen stars just east of Procyon was pictured as a serpent and was called Hydra, the Water Snake. Its diamond-shaped head crosses the meridian immediately behind the Little Dog and its long body



extends to the southeast below Regulus in Leo and Spica in Vergo and even reaches below the horizon. As the constellations continue their never-ending procession toward the west this swift gliding serpent wriggles silently behind the Little Dog vainly attempting to get close enough to strike.

Immediately north of the Water Snake is the Crab and the proximity of these constellations seems to have suggested the

Second Labor of Hercules, the sun-god, with which all readers of Greek mythology are familiar. Hercules was forced to give battle to the Hydra of Lerna, a giant water snake with seven heads, while the crab pinched his heels, and to his dismay every time he cut off one head seven more sprang out in its place. Realizing that he was engaged in a hopeless task our hero decided to burn off the heads rather than cut them off and in this way he finally succeeded in destroying the monster.

The Greeks probably gave the Hydra seven heads because of its great length, requiring a little more than seven hours to cross the meridian. Of course as the Water Snake crawls down below the western horizon its head (stars) are cut off one at a time only to appear again the next evening in the east. But when the sun arrives at a certain position in the Zodiac Hercules (the rising sun) surprises the Hydra in the eastern sky at dawn and burns off its heads with its dazzling heat, causing the monster to disappear completely.

All of the stars in Hydra are very dim with the exception of one of the second magnitude, a dull red star known to the Arabs as the "Solitary One." Tycho called this star "the Heart of Hydra," the name by which it is known today.

The head of Hydra is represented by a group of stars lying between Regulus and Procyon and rises at sunset slightly north of east about the middle of February. On the second of March it is on the meridian immediately behind Procyon at ten o'clock and it remains in the evening sky until the middle of July.

TWO LIONS ARE NEAR THE BEARS

On the Celestial Chart that was prepared by Hevelius of Danzig and published in 1690, almost three years after his death, the eighteen stars between the constellations Leo—the Lion—and the Great Bear—the Big Dipper—are grouped into a separate constellation which he called the Lesser Lion. He probably saw some resemblance between this star-group and the nine stars that form the sickle and the triangle in Leo. His imagination, however, was much greater than ours for we can see no such similarity, at least not to compare with the resemblance

between the Big Dipper and the Little Dipper. The stars in this part of the sky were not grouped into a separate constellation by Ptolemy and the early Greek scientists but were included in the constellation Leo, and both Lions were included in the great figure which the Chinese called the Dragon.

The Lesser Lion is very inconspicuous and is rather difficult to identify. The Greater Lion—Leo—is well known to all watchers of the sky and should be located first. Then look for the group of seven dim stars of the fourth and fifth magnitude almost directly between Regulus and the Pointers. See if you can find the Lesser Lion near the middle of March almost directly overhead and just east of the Zenith at ten o'clock in the evening.

A SEXTANT LIES BURIED IN THE SKY

Among the new constellations that appeared for the first time on the Chart of Hevelius is Sextans—the Sextant. The reason for this name is not very obvious for the seventeen naked-eye stars between Leo and Hydra do not in the least resemble a sextant. Hevelius devoted much time and energy to the careful measurement of the stars and constellations and he may have placed this celestial Sextant in the sky to commemorate the crude instrument with which he worked.

Near the middle of March the dim stars forming the Sextant will be seen crossing the meridian at about ten o'clock in the evening. See if you can identify them south of the Zenith. The brightest star in the group is of the fourth magnitude and lies about twelve degrees south of Regulus, and the entire constellation will be found between Leo and Hydra.

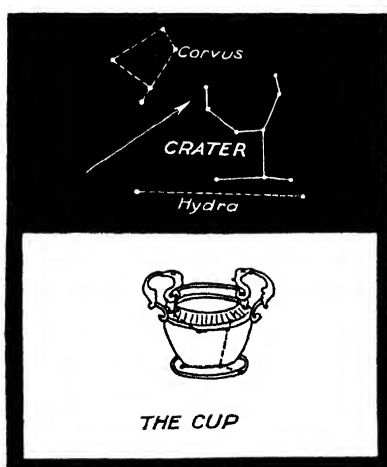
THE CUP RESTS ON THE HYDRA

Just west of the Crow and closely identified with it is a group of inconspicuous stars which form the constellation known as Crater—The Cup. This is one of the very few constellations that resemble the object after which they were named, for if we draw

an imaginary line connecting the brighter stars in the Cup we trace out a bowl-shaped figure.

Although this constellation is inconspicuous and somewhat difficult to identify it is probably as old as most of the others. It has usually been represented as a large urn with two handles that rested on the coils of the great sea serpent, Hydra. This curious picture of an urn resting on a serpent must have been a part of the familiar star lore of early peoples for Aratus the celebrated Greek poet of the third century B. C., in his description of the Hydra says, "midway his volume is the Cup."

The tribes in the Euphrates Valley called this constellation "The Bowl of the Snake." It was also known to the Romans as



"The Goblet of Apollo" and to the Greeks as "The Cup of Herakles," the association being in each case with the sun-god rather than with a snake. For some unknown reason the Chinese pictured this group of stars as a Dog.

It is only natural for primitive peoples to picture the Crow, the Cup and the Hydra together in the same part of the sky. To them the Cup was symbolic of that inverted bowl they called the sky, in which clouds, rain, wind and storms were brewed. The Crow was known as "The Great Storm Bird," and Hydra was frequently referred to as "The Storm Monster."

The nine stars in the Cup are not of special interest since none of them are brighter than the third magnitude. However, this dim constellation can be easily identified on any clear moon-

less night immediately above the tail of the Hydra and about thirty degrees west of the bright star Spica in Virgo. It will be found in the southern sky near the meridian about ten o'clock in the evening on April 13. Look for the Cup about fifteen degrees south of the equator.

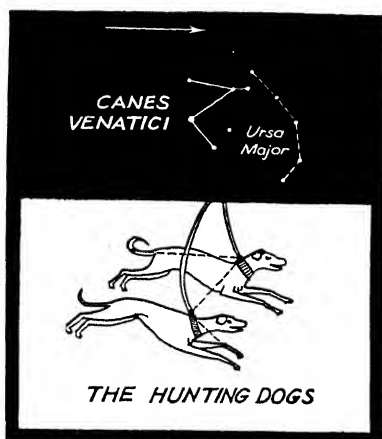
THE HUNTING DOGS CHASE THE BEAR

The stars in the northern sky naturally attracted the attention of early races living north of the equator, for they climbed the sky in long trails from the northeast toward the south and then descended toward the northwest. These stars spent very little time under the horizon and were usually in plain view somewhere in the sky on any night in the year. If they were close enough to the north celestial pole they moved in circular paths around this imaginary point and were never hidden below the horizon—a fact that is known to very few modern people, although we consider ourselves both cultured and educated. It was this part of the sky that attracted the admiration of our prehistoric ancestors and it was here that they, by making use of the silver fire of the stars, burned indelibly into the dark background of space the legend of the rescue of the princess Andromeda by Perseus and many of their other fables. Here the Great Bear moved daily around the pole followed by Boötes—the Bear Driver—who, as the poet Aratus says, was “behind and seeming to urge on the Bear.”

Up to the time of Hevelius of Danzig all of the dim stars between the Great Bear and the orange Arcturus were considered as a part of the Bear Driver rather than as a separate constellation. But Hevelius seems to have felt that it was beneath the dignity of this celestial bear keeper to chase a bear around the pole without the assistance of one or more dogs and so on his Celestial Chart published in 1690 we find a small star-group immediately behind the Great Bear pictured as two dogs which the Bear Driver holds in leash with his left hand. This constellation is now known as *Canes Venatici*—the Hunting Dogs.

Although this dim constellation contains no stars brighter than the third magnitude, there are several objects in this region that

are of special interest. The brightest star in the Hunting Dogs—sometimes called “Charles’s Heart” in memory of Charles I—is a wide double and easily separated by a very small telescope.



This constellation also contains the great Whirlpool Nebula, one of the spirals discovered by Lord Rosse near the middle of the nineteenth century. Look for the Hunting Dogs high in the sky and almost in the zenith at ten o'clock in the evening near the end of April.

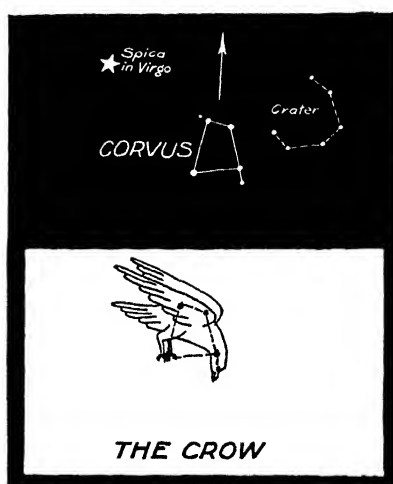
ABOVE THE HYDRA FLIES THE CROW

East of the Cup and immediately above the Hydra is a group of stars which, although covering a very small section of the sky, has been recognized from very earliest times as a separate constellation. On ancient sky maps these seven stars were pictured as a bird which was known to the Greeks as *Corvus*—the Crow—and usually represented as perched on the coils of the Water Snake—Hydra—and in the act of attacking that huge monster. This was obviously in the mind of the Greek poet Aratus for, in his description of the Hydra, he remarks that, “the figure of a Crow seems pecking at him.”

According to Greek mythology Apollo, the sun-god, was once in love with a maiden by the name of Coronis and instructed the crow to follow her and watch her behavior. When his faithful

bird came back with the news that Coronis was bestowing a part of her affections upon another, Apollo immediately shot an arrow from his silver bow into the breast of the maiden he loved, and rewarded the crow by placing it in the sky. This legend does not account for the fact that the Crow is attacking the Hydra but it does furnish a basis for the story that crows were originally pure white but were later changed to black as a punishment for tale-bearing.

The fact that widely separated races of people pictured this small constellation as a bird—naturally they did not agree upon the species—bears witness to the antiquity of some pre-historic legend that primitive man attempted to write indelibly in the sky.



To the Chinese this was "the Red Bird," the last of the twenty-eight constellations of their Zodiac. To the tribes in the valley of the Euphrates it was "the Great Storm Bird" which they placed next to the Cup, where storms were mixed, and immediately above Hydra—the Great Storm Monster. The Hebrews and Romans retained the black color of the bird but called it "the Raven" and associated it with Noah's Ark, the Dove, and the sacrificial Altar which were also pictured in the sky.

This small group of stars of the third and fourth magnitude may be easily identified during the Spring months. At ten o'clock in the evening near the end of April the Crow may be seen on the meridian in the south just a few degrees southwest of the bright star, Spica.

BERENICE'S HAIR ADORNS THE SKY

On any clear moonless night during the Spring months, while watching the Bear Driver and his Hunting Dogs chase the Great Bear around the pole, your attention may be attracted to a faint yet beautiful cluster of stars immediately west of Arcturus. Early peoples took much interest in this cluster which was originally a part of the constellation Virgo and represented the sheaf of wheat held by the Virgin of Harvest. The Greek scientist Eratosthenes of the School at Alexandria seems to have been the first to give this faint star-group a special name. He called it "Ariadne's Hair," probably associating it with "Ariadne's Crown" of seven stars—the Northern Crown—which Bacchus removed from the beautiful tresses of his dying wife and tossed into the sky to form a constellation. Ignoring this pagan legend the early Christians preferred to associate this cluster with Samson and Delilah and called it "Samson's Hair."

Ariadne's Hair is not the only cluster of stars in the sky. We are all familiar with the famous Pleiades, which fix the date of Hallowe'en, and with the Hyades in which Aldebaran shines. Just as the brighter clusters—the Hyades and the Pleiades—have always been allowed to contribute their part to the picture of the Bull, so also should we have expected this dim cluster to have retained its position in Virgo, but such was not to be the case. When Tycho's catalogue was published in 1602 the cluster was listed as a separate constellation—Berenice's Hair.

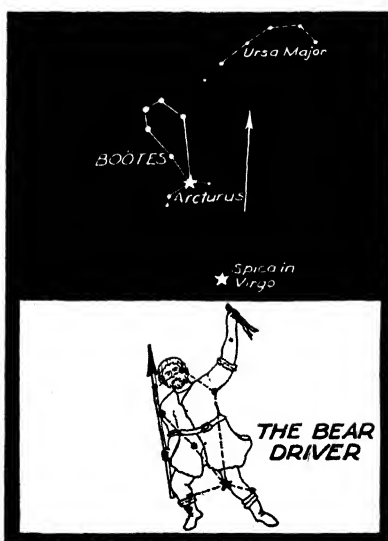
According to an old legend Berenice, a famous Egyptian queen, vowed to dedicate her hair to the goddess of beauty if her husband should return safely from a war with the Assyrians. Soon after his return she deposited her locks on the altar in the temple of Venus only to have Jupiter snatch them away and place them in the sky.

If you will examine very closely the section of the sky between Virgo and the Hunting Dogs you can easily identify this beautiful cluster. The light of the moon may erase it temporarily from the sky, for this cluster is not as bright as the Hyades and the Pleiades, so you should select some clear evening when the moon is below the horizon. About ten o'clock in the evening near the

first of May look for Berenice's Hair on the meridian about twenty-five degrees west of Arcturus.

BOÖTES DRIVES THE BEARS

Early peoples seem to have considered it necessary to have someone in the sky to look after the Bears—Callisto and her son—as they glided silently round the pole star, for they picked out a small group of stars in that part of the sky and called this constellation Boötes, a word which means a Herdsman. Although this kite-shaped constellation can by no stretch of the imagination be made to resemble a human being, we find on the



early star maps a picture of a man. He holds a spear in his right hand and holds in leash two hunting dogs with his left and is supposed to be driving the bears. He can be seen every clear night chasing the Big Bear around the pole.

Those peoples who called the Big Dipper "the Plough" naturally gave the name "Ploughman" to this star-group. Because it was not very far from the pole and appeared to be holding up the heavens, Boötes was sometimes called "Atlas." You will recall the Greek legend about the demi-god Atlas who supported

the heavens on his shoulders until he was turned into a mountain by looking into the face of Medusa.

If the curved line which forms the handle of the Big Dipper be extended away from the bowl a distance approximately equal to twice its original length, it will reach a bright orange star of the first magnitude which early peoples placed in the left knee of Boötes. This is Arcturus, one of the best known stars of early times. Arcturus was mentioned by Homer, Hesiod, and by the author of the Book of Job. When Donati's Comet made its visit to the earth in 1858 the brilliant Arcturus could be seen shining brightly through the head of the comet.

For some reason Arcturus was supposed by the ancients to be the nearest star to the earth and to have quite an influence on the human body. We now find that this really is not a remarkable star and that its distance is about forty light years, there being several bright stars closer to us. Arcturus is rather small, as stars go, its diameter being only about twenty-seven times the diameter of the sun. Although Arcturus is 100 times as bright as the sun, its surface temperature (4000°), like that of other red and orange stars, is less than that of our own celestial furnace.

ARCTURUS IS THE BEAR KEEPER

To the average person the word "Arcturus" is merely the name of a star, but to one who is familiar with the Greek language the significance of this word is apparent. The Greek word "Arktos" means a bear and the word "ouros" means a guardian, so that the Greeks actually called this star the "bear guardian." It is probable that Arcturus was the original name for the entire constellation. Of course the group of stars including Arcturus which form the constellation known as the Herdsman does not in any way resemble a man. However, after the two Bears had been placed in the sky people probably felt that it was necessary to have someone near to look after them, so they assigned this duty to a near by star-group. It was in this way that the early races wrote their legends indelibly in the sky in such a way that they could never be erased, and thus did the stars get their names.

Arcturus is the most rapidly moving first magnitude star, its velocity being more than 200 miles per second. Since the time of Ptolemy its apparent position in the sky has shifted a distance of more than twice the apparent diameter of the moon.

With this thought in mind we can understand what the author of the Book of Job meant by the question, "Canst thou guide Arcturus?" To the student of astronomy this question has a hidden meaning. God is reminding Job that He can guide the fastest moving star in the sky. Of course there are other stars moving more rapidly but they cannot be seen without optical aid. How can we expect to really understand the Bible or any other piece of ancient literature until we are familiar with our universe?

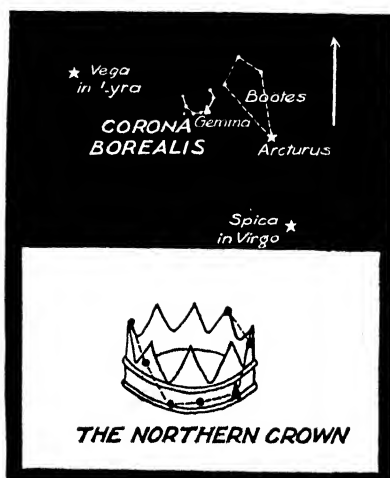
The star Arcturus can be easily identified for there are only two brighter stars visible to those who live north of latitude forty degrees. It rises at sunset early in April about twenty-five degrees north of east and remains in the evening sky until early in November. On the twenty-fourth of May it will be found on the meridian at ten o'clock about twenty degrees north of the equator. Watch for Arcturus. The bright star to the south and west is Spica in Virgo and the other bright one a little farther south and to the east is Antares in Scorpio. Note the difference in their colors.

BACCHUS THREW ARIADNE'S CROWN INTO THE SKY

Another well known constellation is the Northern Crown, sometimes called Corona. This is one of the very few star-groups that really resemble the object after which they were named, for it consists of a small circle of eight stars which might very easily suggest a crown. Some of the North American Indian tribes, as they sat around their camp fires on summer evenings, noticed this circle in the sky. They imagined that the Great Spirit was holding a conference with his subjects around some heavenly camp fire and this small circle of stars began to be called the Camp Circle.

Perhaps you are wondering how this crown got into the sky.

One day Bacchus, the god of wine, discovered the fair maiden Ariadne in the forest and, having won her as his bride, presented her with a crown adorned with seven glittering gems. Shortly after their marriage Ariadne became ill and died and Bacchus, in order to do away with the beautiful crown which he had so often seen upon her head and which constantly reminded him of his sorrow, tossed it up into the air. The crown rose higher



and higher until the gods fixed it in the sky where it still forms the beautiful and conspicuous constellation Corona, sometimes known as "Ariadne's Crown."

Although there are no bright stars in Ariadne's Crown this constellation may be easily identified because of its shape. Near the middle of April it may be seen rising at sunset about thirty-five degrees north of east and every night thereafter until early December it will be conspicuous in the evening sky as it follows Arcturus toward the west. One of the most celebrated temporary stars of the nineteenth century blazed out in this constellation on May 12, 1866, and remained visible for eight days. The brightest star in the Crown is only of the third magnitude, but early peoples considered it to be of sufficient importance to deserve a name. It has been called Gemma and "the Pearl of the Crown." The Coronids, a meteor shower that is visible every year from April 12 to June 30, appear to radiate from a point in the direction of this star.

On the twelfth of June, Ariadne's Crown may be seen at ten

o'clock on the meridian about thirty degrees north of the equator. Look for it almost in a line with the orange Arcturus and the bluish-white Vega.

MAN DESTROYS THE SERPENT

The sun was the principal god of primitive peoples and was worshipped each morning at sunrise as he returned victorious from his battle with the demons of darkness. At the end of every year when the sun was far in the south and seemed to be on the point of losing most of his heat and light, he was always "born again" and soon returned triumphantly to the north for the benefit and comfort of mortal man. Thus it was only natural for all races of people to perform certain religious rites at sunrise and to celebrate a great sun festival—we now call it Christmas—at the end of the year.

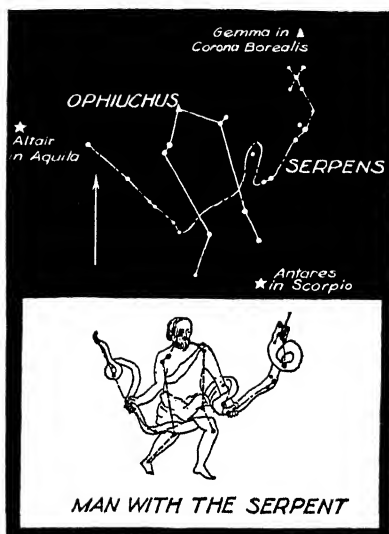
The perpetual warfare between man and the serpent—the symbols of the powers of good and the powers of evil—was the basis of many early myths and legends. We recognize it not only in the classical reference to the battle between the newborn Hercules and the serpents that were sent to his cradle by Juno, but also in the Hebrew story of the serpent in the Garden of Eden at the birth of the human race.

We are accustomed to finding ancient legends written in the sky, but this one—perhaps the most universal of all—is preserved for future generations in, not merely one, but at least two groups of constellations. Near the "top of the sky" we see Hercules with his foot on the Dragon and in the "center of the sky," midway between the Vernal and Autumnal Equinoxes, is the Serpent Holder with the Serpent in his hands and the Scorpion under his feet.

At least 5500 years ago a widely scattered group of about thirty rather dim stars lying between Scorpio and Hercules was pictured as a man with both hands grasping the coils of a great serpent whose head reached almost to the Northern Crown. The stars that belonged to the figure of the man were later considered as a separate constellation which was named Ophi-

uchus, from two Greek words meaning "the man that holds the serpent."

Look for the diamond-shaped head of the Serpent about fifteen degrees south of the Northern Crown. It will be on the



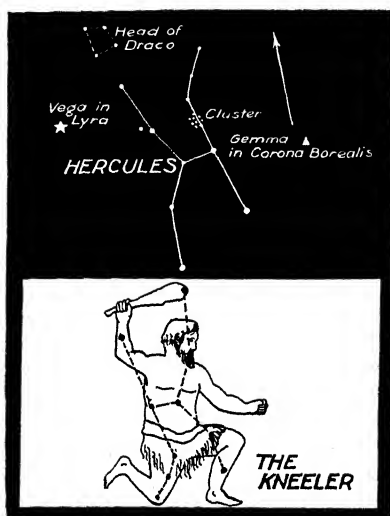
meridian high in the south at ten o'clock near the middle of June. The brightest star in Ophiuchus—in one eye of the Serpent Holder—lies about twenty-five degrees east of the serpent's head.

THE GIANT HERCULES TREADS ON THE DRAGON

Immediately east of the Northern Crown is a group of about twenty-seven dim stars which was pictured on the early star maps as a giant in a kneeling position with his right foot on the head of Draco, the Dragon. This is Hercules, the Kneeler, the grandson of Perseus who rescued Andromeda from the sea monster. The stars in this constellation are all rather dim and it is a little difficult to understand why such an inconspicuous star-group deserves the dignity of being called a constellation, yet Hercules seems to be much older than several others that are much more easily identified.

The never-ending warfare between good and evil, which is

symbolized by the conflict between man and the serpent, has been a popular subject for the poets of all ages. The Dragon had been placed near the North Pole to guard the stars and it was necessary to have this monster under the heel of someone. Who could fill this position better than the giant Hercules who, from the very hour of his birth, was forced to struggle with snakes and monsters of different kinds. Just south of Hercules and extending into the southern sky is Ophiuchus, the Ser-



pent Bearer, another giant with his foot on the head of the Scorpion. These four constellations seem to have been arranged as they are for a definite purpose. When Hercules is on the meridian we may look into the north or the south and in either case we will see a giant treading on a serpent. Who can study the heavens and then say that there was not a specific reason for every design written indelibly in the sky by primitive man?

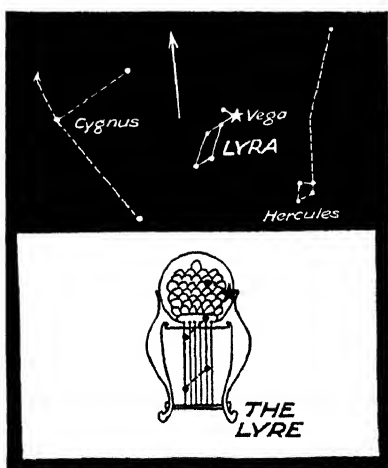
In Hercules is a wonderful star-cluster, discovered by Edmund Halley in 1714 and known for some time as "Halley's Nebula." This familiar object, which modern telescopes have resolved into at least forty thousand separate stars, is one of the two open clusters visible to the naked eye.

Hercules rises at sunset almost in the northeast early in May and in June, when Arcturus blazes almost directly overhead and Vega is rising in the east, this constellation can be very easily seen between them. It is on the meridian about thirty degrees

north of the equator at ten o'clock on the fifth of July and remains visible in the evening sky until the middle of December.

THE SOLAR SYSTEM IS MOVING TOWARD LYRA

A celebrated northern constellation is Lyra, sometimes called the Harp, containing the bright blue star Vega, which forms an isosceles triangle with Arcturus and the Pole Star. There is only one star (Sirius) visible to observers north of latitude forty degrees that is brighter than Vega. Not far from Vega is the



point in the sky toward which the sun, accompanied by the entire solar system, is moving in its headlong plunge through space at the rate of 250 million miles per year. Another interesting object in Lyra is the celebrated Ring Nebula which, although visible only through a telescope, is the brightest nebula of its kind.

On account of the precession of the equinoxes the north pole of the heavens is slowly moving in a circle around a certain point in the sky. About 14,000 years ago the pole was very close to Vega so that this star was moving so slowly that it could be measured only with extreme difficulty. This perhaps explains the origin of the name of the constellation for both the Greek and the Latin words for the musical instrument which we now call the "lyre" also mean a "tortoise," an animal which is noted for its slow motion. In about 11,500 years Vega will again be the

North Star and all other stars will appear to rotate about this brilliant gem in the sky.

We learn from classical mythology that Mercury constructed a lyre out of the back of a tortoise and presented it to Apollo, who passed it on to his son Orpheus. By playing beautiful strains on his lyre Orpheus later rescued his wife from Hades but he soon lost her again and thereafter he could play only mournful tunes. This resulted in his being killed by those who wished to be gay and to enjoy life. Apollo then took back the lyre and placed it in the heavens as a bright constellation.

Vega may be easily identified just back of the bowl of the Little Dipper. It rises in the northeast at sunset near the middle of May and follows Ariadne's Crown across the sky. This blue star, which has also been called "the Arc-light of the sky," is visible somewhere in the northern sky at sunset until the middle of January. Look for it on the meridian forty degrees north of the equator at ten o'clock on the thirtieth of July.

SOBIESKI'S SHIELD PROTECTS THE STARS

To those who are familiar with the constellations, the sky is a revolving picture book in which man has successfully preserved for all time the folk-lore of many thousand years ago. With the fire of the stars he sketched against the dark background of the sky those fanciful figures—we sometimes call them "asterisms"—of his mythical heroes and the terrible monsters and other creatures about whom the poets continually sang. The complete story could be easily read without turning the pages of the book, for nature obligingly set the sky in motion so that daily each picture would in turn appear above the eastern horizon and move westward across the heavens until erased by the brilliant glare of the rising sun and then, for the sake of variety, she arranged to have the stars gain four minutes on the sun every day so that with the recurring seasons the constellations one by one would escape from the sun's rays and occupy a favorable position for observation.

As we study our celestial picture book during the summer season we see the Scorpion riding westward on the Milky Way

pursued by the Archer with his deadly bow. Standing on the Scorpion is the giant Ophiuchus, from whose powerful grip the Serpent is vainly attempting to escape. Flying behind Ophiuchus and in the Milky Way, the Eagle joins the celestial menagerie.

There are eleven dim stars between the tail of the Serpent and the head of the Archer that were not needed to make up the picture of either the Scorpion, the Archer, the Eagle, the Serpent, or the Serpent Holder. Thus these stars attracted no attention until Hevelius of Danzig noticed that they had been overlooked and introduced them as a new constellation which he called "Sobieski's Shield" in honor of the third John Sobieski, King of Poland. On his map of 1690 this group of stars was represented by the Coat of Arms of that renowned warrior.

None of the stars of the Shield—or Scutum, if we prefer the Latin word—are brighter than the fourth magnitude so that this constellation is very inconspicuous. It lies deeply buried in the Milky Way between the red Antares in the Scorpion and the white Altair in the Eagle. The Shield will be on the meridian about ten degrees south of the equator at ten o'clock in the evening near the end of July. Look for it directly south of Vega.

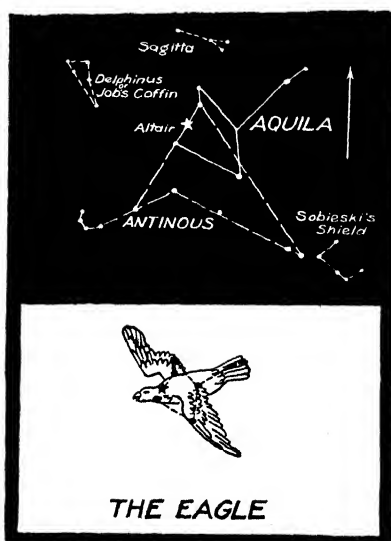
AQUILA IS THE EAGLE THAT CAPTURED GANYMEDE

Between Lyra and Sagittarius lies the conspicuous constellation Aquila, the Eagle, whose origin can be traced back to very early times. This star-group was known as the Eagle to the pastoral people of the Euphrates Valley at least twelve centuries before our era. The Turks referred to this constellation as "the Hunting Eagle," as contrasted with Lyra near by, which they called "the Falling Eagle." Just east of the Eagle is the constellation Aquarius, with which it is closely associated in classical mythology.

The Greeks noticed Aquila and Aquarius—the one an eagle and the other a man holding a bowl in his hand—close together in the sky and invented the legend about Jupiter and Ganymede to explain their existence. Once upon a time Jupiter, the king of the gods, became dissatisfied with Hebe, his cup-bearer, and

found it necessary to discharge her. Whereupon he assumed the form of an eagle and, after searching the entire world for a beautiful young man, kidnapped Ganymede, the son of the King of Troy, and flew with him to Mount Olympus where he was installed as cup-bearer at the banquets of the gods.

You can easily locate Aquila by drawing an imaginary line across the sky from the Little Dipper to Vega and then producing it until it is about twice its original length. It was in this constellation that the bright Nova, or temporary star, was



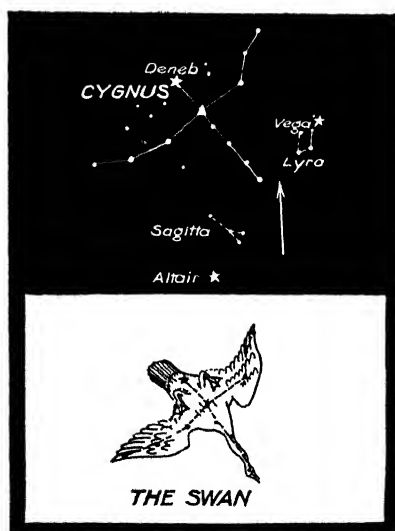
found in June, 1918, and we also have records of another Nova which appeared in Aquila about 389 A.D. and was brighter than Venus. Look for a brilliant star of the first magnitude in the Milky Way with a bright companion on either side at a distance about equal to four times the apparent diameter of the moon.

The bright star in Aquila is Altair, in the eye of the Eagle. Although the light from this star does not reach the earth until sixteen years after it has been radiated into space, Altair is actually nine times as bright as the sun. In the evening twilight of late June Altair will appear on the horizon about ten degrees north of east and will gradually drift toward the west until it is lost in the rays of the setting sun in late January. Near the middle of August it may be seen on the meridian at ten o'clock about eight degrees north of the equator.

THE NORTHERN CROSS HAS ATTRACTED
ATTENTION IN ALL AGES

Immediately east of the constellation Lyra and imbedded in the Milky Way lies a star-group known as Cygnus, the Swan. The brightest stars in Cygnus form the "Northern Cross." There are five stars in the upright part of the cross, the brightest star in the constellation being at the top. The cross-piece is marked by two bright stars, one at either extremity. About nine P. M. during the Christmas season this celestial cross stands upright on the western horizon, a beautiful symbol of Christian faith.

In classical mythology we find several legends which account for the presence of a swan in the sky. One day the sun-god



Apollo reluctantly allowed his son Phaeton to drive the sun-car, in spite of the fact that this tender youth was not trained to combat the many monsters that awaited him along the Zodiac. After the fiery steeds had been stung by the Scorpion this undertaking ended in disaster and Phaeton was hurled from the car into the River Eridanus. His intimate friend, Cygnus, vainly attempted to locate Phaeton's body by plunging again and again into the water until the gods finally changed him into a swan

in order that he might look for his friend with more ease. This story, like the others of primitive times, was written indelibly in the sky. A group of stars east of Lyra and resembling roughly a bird in its flight from north to south was called Cygnus and a second group in another part of the sky was named the River Eridanus.

According to another legend the swan represents Orpheus, who, after his death, was changed into a swan and then, with his celebrated lyre, transported to the sky.

The Arabs called Cygnus "the Flying Eagle," and sometimes "the Hen." The brightest star in this constellation they called "Deneb," meaning "the Hen's Tail." Deneb is only slightly brighter than Regulus but were it not for the fact that it is about 650 light years from the earth this star would be brilliant indeed. Its actual luminosity is about the same as that of Canopus, Rigel, and Antares, being about 14,000 times as bright as the sun.

Cygnus rises at sunset near the middle of June about fifty degrees north of east and remains in the evening sky until late in January. Early in September Deneb may be seen on the meridian at ten P. M. about forty-five degrees north of the equator.

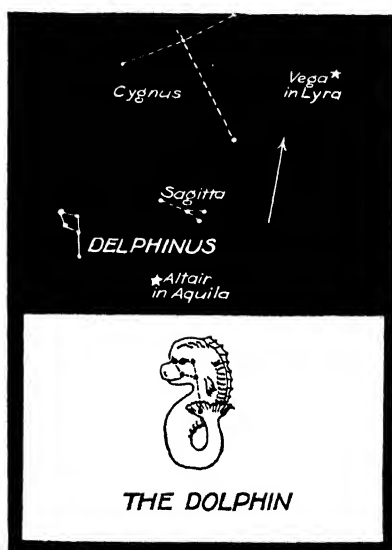
THE DOLPHIN PLAYS IN CELESTIAL SEA

One of the oldest and most interesting of the small constellations is Delphinus—the Dolphin—which was the name given by early peoples to a little group of five stars immediately northeast of Altair in the Eagle and southeast of the Arrow. This curious fish, to which reference is frequently made in classical literature, was correctly placed in that great "Celestial Sea" that covers such a large section of the heavens. The Dolphin is swimming playfully not far from the Sea-Goat and near the "shore" of this imaginary ocean, and farther out into the celestial "depths" we find those other maritime creatures, the Whale, the Fishes, the Southern Fish, and the Winged Horse—created by Neptune in a terrestrial ocean and later transferred to the sky.

Although this small star-group appears as a separate constellation on most early star maps, the origin of the name is

by no means certain. The Arabs, who naturally knew very little about seas and oceans and were much better acquainted with the beasts of the desert than with maritime creatures, called it "the Riding Camel"; but the ancient poet Aratus, in his beautiful word-picture of the heavens, says "the Dolphin small to sight floats over the Goat," and the constellation appeared under this name in Ptolemy's catalogue and in all subsequent ones.

The following classical legend may perhaps explain the existence of the Dolphin in starland. Venus, the goddess of beauty,



who was born from the foam of the sea, once made a vow that she would always retain her freedom and would never be the wife of any god or man. Swimming in the sea was one of her favorite sports and she was usually attended by a school of friendly dolphins which swam, not under the water as ordinary fish usually do, but with their backs above the waves. Finally Neptune, the god of the sea, won her as his bride with the assistance of one of these dolphins and he later transferred it to the sky as a reward for faithful service.

None of the stars of the Dolphin are brighter than the third magnitude, yet it is a rather conspicuous star-group. It is best known as "Job's Coffin," probably because four of its stars form a small rectangular figure somewhat resembling a coffin. Look

for it on the meridian about twelve degrees east of Altair at ten o'clock in the evening early in September.

THE FOX HIDES IN THE MILKY WAY

When Hevelius of Danzig undertook the task of assigning names to all parts of the sky that were not already named from some well known star-group, he necessarily invented several new constellations. He noticed a section of starland, immediately south of the large Northern Cross and north of the small Dolphin and Arrow, that was not needed to complete either of these asterisms, and in his *Celestial Chart* published in 1690 this small area was labeled "*Vulpecula cum Anser*" for in those days it was the fashion in his part of the world to give Latin names to all of the constellations. Today many of us prefer to use the English translation which is "The Fox with the Goose." Just why Hevelius chose this name will probably never be known.

In our star catalogues the Latin names of the constellations are still used, so that the beginner is sometimes confused by hearing a group of stars called by two different names. This confusion, however, is only temporary for, even though he may not have studied Latin in his school days, he soon learns that Aries and the Ram are one and the same and that Taurus means the Bull, and he recognizes the Eagle, the Dragon and the Lion even when they are called *Aquila*, *Draco* and *Leo*. For convenience the name of the constellation we are now discussing has been shortened to *Vulpecula*—the Fox.

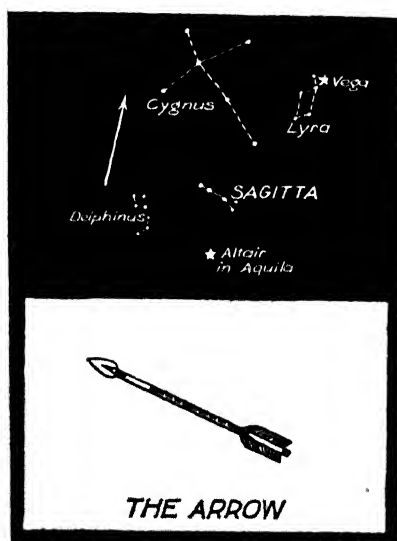
Like the Sextant, the Crater, the Crow and the Shield, *Vulpecula* contains no stars brighter than the third magnitude and is rather inconspicuous but, when viewed through the telescope, this section of the sky contains several objects of more than passing interest, not the least important of which is the mass of nebulous material known as the Dumb-Bell Nebula.

Perhaps the best way to locate *Vulpecula* is by means of certain bright stars and the Milky Way. Begin with the red Antares in the Scorpion and travel—with your imagination—northward and eastward along the Milky Way. Leaving the Scorpion you will cross the Archer and the Shield and encounter the Eagle.

Soon after you pass Altair you find the Arrow, where the Milky Way divides into two separate streams of stars and, just before you enter the region of the Northern Cross, you meet Vulpecula—the Fox—which will be found near the meridian at ten o'clock in the evening near the beginning of September.

SEVERAL ARROWS FLY THROUGH THE SKY

In the Milky Way immediately north of the Eagle is a group of four dim stars which was represented on the star maps of many ancient nations by an arrow. The connection between this constellation and the Eagle is not quite apparent, unless it repre-



sents the arrow with which the hero of some classical legend slew some bird of prey. Such legends are numerous in ancient literature. On a few early star maps the Eagle was pictured with an arrow in his talons, which probably accounts for some of the modern pictures of an eagle holding one or more arrows in his claws.

At any rate this constellation was known to the Arabians, Armenians, Persians, and Hebrews as the Arrow and this name has come down to us through the ages. The Latin equivalent, which is frequently used, is Sagitta. In this part of the sky ar-

rows are plentiful. On one side of the Eagle (the south) the Archer aims his arrow at the Scorpion and on the other side is the Arrow, but without an archer or even a bow.

The Arrow may be seen on the meridian high in the sky at ten o'clock in the evening about the middle of August. None of the stars are brighter than the fourth magnitude, the brightest one being in the tip of the arrow which is pointed toward the east. Look for it about ten degrees due north of the bright star Altair.

THE LIZARD IS NEAR THE PRINCESS

Another constellation composed of very dim stars is Lacerta—the Lizard—which is the name given by Hevelius to that region of the sky lying between Andromeda and the Northern Cross. This part of starland was known to the Chinese as "the Flying Serpent," but the name proposed by Hevelius is the one now in general use.

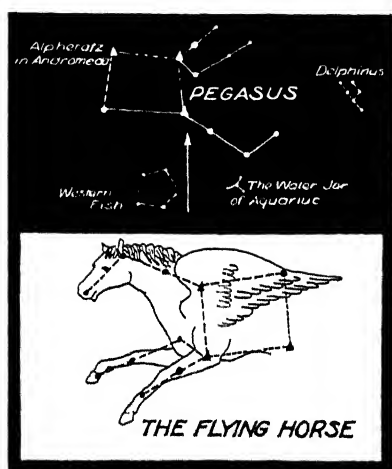
The Lizard is very inconspicuous and contains no stars brighter than the fourth magnitude. Neither is it marked by any recognizable tracings such as are to be found in the Arrow and the Dolphin and which, though formed of rather dim stars, serve as a means of identification. Look for it near the meridian and just east of the Northern Cross at ten o'clock in the evening near the first of October.

PEGASUS FLEW UP OUT OF THE SEA

After his victory over Medusa Perseus continued his flight over land and sea and finally came to that part of the earth where the demi-god Atlas was supporting the heavens on his shoulders. Now Atlas had been on this job for a long time, his burden had become very heavy and he was anxious to be relieved of his task. He saw Perseus coming with the head of the Medusa in his hand and, realizing that here was a chance to escape from his burden, he begged Perseus to give him just one

look at the face of Medusa. Perseus felt sorry for him and gladly granted his request, whereupon Atlas was immediately transformed into the mountain range which still bears his name. From that day to this the heavens have been supported, not by the demi-god Atlas, but by those mountains in northwestern Africa whose lofty peaks apparently extend into the sky.

Perseus then went on and on and the blood dripping from the head of the Medusa onto the sandy desert of northern Africa was transformed into those poisonous serpents which are so common in that part of the world. As he flew over the ocean and the blood began to drip into the water Neptune, the god of the sea and a former husband of Medusa, trans-



formed this blood into that winged horse, Pegasus, which flew up into the sky and became the favorite mount of Jupiter, Apollo and the other gods. It was this same winged horse, Pegasus, as white as snow and gifted with immortal life as well as incredible speed, that carried Perseus to the rescue of the princess Andromeda.

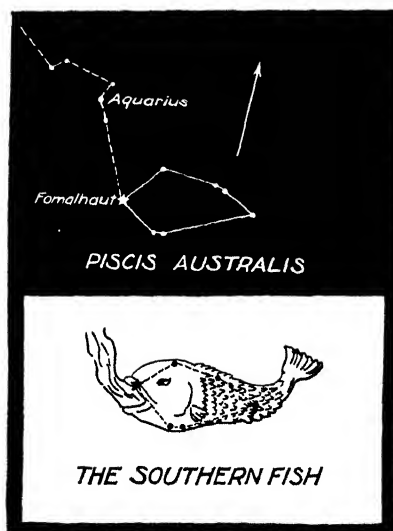
On all early star maps the region immediately north of the Western Fish is called Pegasus and is represented by a horse with wings. For some reason only half of the horse is shown and that upside down.

There are four bright stars in this constellation which form a large square, called the Square of Pegasus. The horse's head stretches out toward the west and all through the autumn the

beautiful Winged Horse can be seen flying westward across the sky. He begins these nightly flights early in September and is visible every evening until February, when he flies down below the western horizon immediately after the setting sun. Look for the square almost overhead at ten o'clock early in October.

THE SOUTHERN FISH SWIMS IN CELESTIAL SEA

In that part of the sky known as the "Celestial Sea" and immediately south of Aquarius lies the constellation made up of one bright star and several dim ones and known as the Southern Fish. On the early star maps these two constellations were very closely associated. Aquarius was represented by the picture of a man pouring water out of a jar, which ran down the sky in a



great stream and emptied into the open mouth of the Southern Fish.

As in the case of most other constellations it is possible to find a classical legend which accounts for this creature being in the sky. Venus was very fond of swimming and enjoyed a daily bath in the sea. One day the monster Typhon approached her and, in order that she might escape from his horrible advances,

she quickly assumed the form of a fish and hid herself in the "Celestial Sea." According to another legend the Southern Fish was the mother of the Northern Fish and the Western Fish that make up the near-by constellation Pisces—the last constellation of the Zodiac.

The Southern Fish really belongs to the southern hemisphere. It is so close to the south celestial pole that in our latitude it is above the horizon only a few hours every day, and when it is visible it is in such a low position that the constellation as a whole is not very conspicuous. However, it contains one first magnitude star which may be seen from all parts of the United States as it describes its low, short arc across the southern skies during the autumn months.

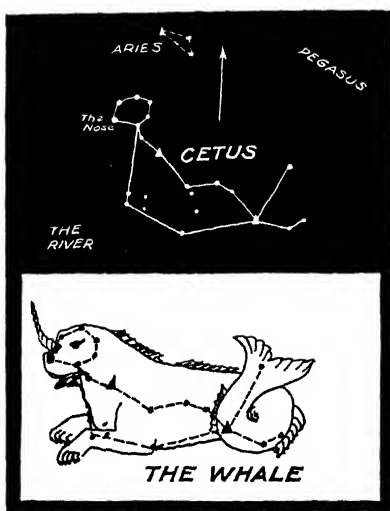
This bright star, to which Aratus refers as "One large and bright by both the Pourer's feet," was known to the Arabs as Fomalhaut—the Fish's Mouth. Of all the first magnitude stars we can see, Fomalhaut is the farthest south. It has a slight reddish tinge and, although there are twelve brighter stars in our hemisphere, this one is very conspicuous because there are no other very bright stars in that region of the sky.

Fomalhaut was one of the four Royal Stars of antiquity, which ruled over the cardinal points of the heavens. The others were Aldebaran, Regulus, and Antares. It may be seen on the meridian and low in the south at ten o'clock in the evening about the eighth of October.

THE WHALE IS THE LARGEST CONSTELLATION

We come now to the discussion of a constellation that is not only very old but it also has the distinction of being the largest in starland. It extends more than forty-five degrees eastward from Aquarius and fills all of the space immediately below both Pisces and Aries. In this wide area the ancients pictured a strange maritime creature with the tail of a fish and the paws of a beast. Aratus refers to it as "the dusky monster," but the name by which it is known today is Cetus—The Whale—although it must be admitted that it does not in the slightest degree resemble a whale.

Just as the Sea-Goat (Capricornus) was pictured on the western "shore" of the "Celestial Sea," with the feet of a goat resting on the "dry land" to the west and the tail of a fish extending eastward into the "water," so also was the Whale represented on the eastern "shore" with its fish-like tail in the "water" and its paws immersed in the River, which flows out of the "dry" regions occupied by Orion and the Bull. The amphibious character of each creature was necessary because of its location between the celestial water and land and they were made to face in opposite directions in order that each might have its fish-like tail in the "sea."



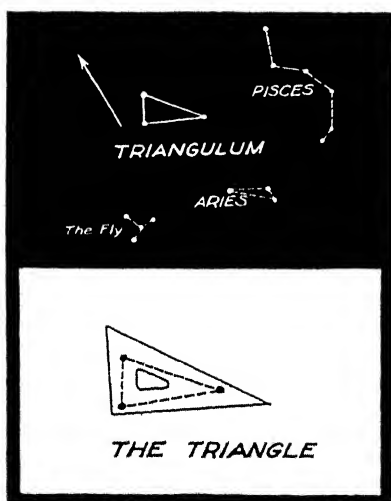
Since there was so much "water" in this part of the sky it was only natural to have some frogs somewhere around, so the Arabs called the brightest star in the Whale—in its tail—the "Second Frog," the first one being represented by the star Fomalhaut about twenty-six degrees to the west in the mouth of the Southern Fish. The most popular name for the Whale is "the Easy Chair," which was suggested by the arrangement of its stars, and it is sometimes called "Jonah's Whale."

The six stars in the head of the Whale, the brightest of which was known to the Arabs as "the Nose," form an almost perfect hexagon and may be easily identified. In its neck is the wonderful variable star Mira which has the distinction of being the first of its kind to be detected. Its period of variability is almost a

year, during which time its brightness increases a thousand fold. Watch for the Whale during the late fall months. Its head will be on the meridian immediately southeast of the little triangle in Aries at ten o'clock in the evening near the end of November.

THE TRIANGLE LIES NORTH OF THE RAM

Early peoples were interested primarily in the brightest and most conspicuous stars. These they combined into groups, using only as many of the dimmer ones in the immediate neighborhood as were necessary to picture—to the satisfaction of their active



imaginations—the mythological characters that were so vividly described by Homer, Hesiod, Virgil and the other poets. Consequently when Ptolemy of Alexandria collected together all of the star lore of his day and gave to the world his celebrated list of forty-eight constellations, many of the dim stars—although plainly visible—were not included.

Fifteen centuries later Hevelius of Danzig decided that the stars should be grouped into constellations in such a way as to cover the entire sky and include all that were visible to the naked eye. With this object in mind he picked out many groups of unclaimed stars and assigned names to them. Since most of these

new constellations are composed entirely of dim stars they are usually rather difficult to identify.

Everyone who is at all familiar with star lore knows that the sky is a picture book in which the heroes of myth and fable are depicted, not in bronze or marble, but by means of groups of stars and only in a very few instances do the constellations bear any resemblance to the characters after which they were named. One noted exception is the Triangle, formed of three stars of the third and fourth magnitude between Andromeda and Aries. This is one of the early constellations that was pictured by Aratus in his poetic description of the heavens, but very little attention is paid to it today. It was here that Piazzzi discovered the first planetoid Ceres, January 1, 1801.

The Triangle may be easily identified. Look for three stars that form a triangle, with two sides of almost equal length, immediately north of Aries. This triangle should not be confused with the smaller one in Aries which the ancients pictured in the head of the ram. It may be seen near the meridian at ten o'clock in the evening during the latter part of November.

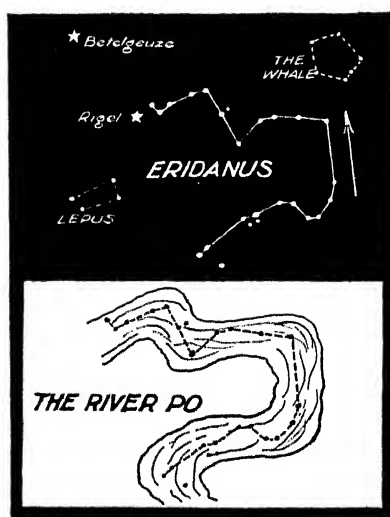
A RIVER FLOWS THROUGH STARLAND

On a clear night, when the moon is not shining and faint stars of the fourth, fifth and sixth magnitude are plainly visible, very little imagination is required to see several crooked lines of stars which early peoples pictured as snake-like monsters of various kinds. Thus Hydra—the Water Snake—with its head immediately east of Procyon and striking at the Little Dog, extends toward the southeast over more than ninety degrees of starland. Draco—the Dragon—is coiled near the “top of the sky” at equal distance from each of the twelve constellations of the Zodiac, but held firmly under the feet of Hercules, and, extending across about sixty degrees of the summer sky, is the Serpent, vainly attempting to escape from the grasp of Ophiuchus.

Immediately southwest of Orion is another crooked line of stars which might have been pictured as a serpent under the

feet of the great Hunter, but primitive man preferred to consider it as a river, winding its way across the winter sky. This star-group has been known from ancient times as the River and has been looked upon as the celestial representation of various terrestrial streams. Among some peoples it was the Nile, to others it represented the Euphrates, and still others preferred to call it the Po. It has also been called the River Jordan and the Red Sea.

It was into this River that—according to the familiar legend—Phaeton was hurled by a thunderbolt of Jupiter on the day he made his wild drive across the sky behind the fiery steeds of his father, the sun-god Apollo. This stream of stars is di-



rectly south of Taurus so that, if the sun was in that part of the Zodiac on this eventful day, there was no other place for Phaeton to fall.

Beginning with the third magnitude star just northwest of Rigel and close to the foot of Orion, which the Arabs called *Cursa* (the footstool), the River runs westward toward the head of the Whale and then turns to the south until it reaches another third magnitude star, known to the Arabs as *Zamack*—meaning "the bright star of the boat." Thence it describes a great horseshoe westward, southward, and eastward. It then flows southward, and again westward, until it reaches the first magnitude star *Achernar*, only thirty-two degrees from the south

celestial pole. Look for the River between Orion and the Whale in November.

SEVERAL BRIGHT STARS CIRCLE THE SOUTH POLE

No study of the constellations would be complete without some reference to several bright stars near the south pole of the heavens which are not visible in the United States. Just as the constellations near the North Star revolve about the north pole without disappearing below our horizon, so also do certain southern constellations revolve about the south pole without coming above our horizon. These extreme southern constellations which never appear in our sky are plainly visible to inhabitants of the southern hemisphere, for the south celestial pole is above their southern horizon a distance equal to their latitude. These people are not able to see the extreme northern constellations with which we are so familiar. In fact, the Little Dipper cannot be seen by anyone living south of the Torrid Zone.

Achernar, which is almost as bright as Procyon, comes to the meridian at ten o'clock on the sixteenth of November but is not visible to those of us who live north of latitude thirty-two degrees. This star is about 200 times as bright as the sun and at a distance of about sixty-seven light years. Canopus, the second brightest star in the entire sky, is only about thirty-seven degrees from the south pole. This star is 14,000 times as bright as the sun and has a surface temperature of about 8000 degrees. Canopus comes to the meridian at ten o'clock on the twenty-fourth of January but is not visible north of Florida and southern California.

No one can visit the southern hemisphere without admiring the Southern Cross, the most interesting of the southern star-groups. The most brilliant star in this constellation is of about the same brightness as Aldebaran and comes to the meridian at ten o'clock on the twenty-ninth of April. This brilliant constellation, so well known to southern navigators, is invisible north of latitude twenty-seven degrees.

The constellation Centaurus contains two very bright stars.

One of these is as brilliant as Vega and the other rivals Procyon in brightness. They come to the meridian at ten o'clock late in May, but neither star is visible north of latitude twenty-nine degrees. The brighter of these two stars was for many years considered to be the nearest star to our sun, being only four and one-third light years away, but recently another star in this same group has been found to be slightly closer to us.

CHAPTER VII

The Depths of Space

EARLY MAN DID NOT UNDERSTAND HIS UNIVERSE

MAN's ideas with reference to his universe naturally changed with the development of the race. In primitive times he felt sure that the changing appearance of the heavens was due to some complicated mechanical device, and many attempts were made to explain the workings of this gigantic machine. The rising and setting of the sun, moon and stars were easily explained on the assumption that the solid sky was rotating about the earth, but the wandering stars (planets) presented a more difficult problem by their unwillingness to remain fixed in the sky.

The Greek philosopher, Aristotle, whose crude ideas were adopted and held sacred by sixty generations of human beings, probably had more influence on human thought than any person who ever lived. He first taught that each planet was attached to a hollow sphere that rotated about the earth but when he discovered that this simple arrangement would not account for certain irregularities in the motions of the planets, he added sphere after sphere until his elaborate machine of fifty-five hollow spheres actually worked. Ptolemy later tried to improve upon the work of Aristotle but made it even more complicated by the introduction of no less than eighty epicycles.

The ideas of Aristotle and Ptolemy were adopted by those in power and for about fifteen centuries very little attention was paid to the motion of the planets because the Creator of the universe was carefully watching all of the heavenly bodies to see that each one appeared in its proper place at the proper time.

In the Middle Ages the astrologers convinced man that the planets had a great influence on his life. He was willing to make

elaborate calculations of the positions of these wandering stars at the time of his birth so as to discover what the future had in store for him. It is hard for us to see how anyone but a superstitious and ignorant person could believe that his life might in any way be influenced by a remote planet or a distant star.

With the publication of the theories of Copernicus in the sixteenth century man began to understand the motion of the planets and soon Tycho, Kepler and Newton revealed the true nature of the solar system. Man now understood that the motions of these wandering stars were determined by their distances, their velocities and their masses, all of which could be accurately measured.

TO PRIMITIVE MAN THE HEAVENS WERE CLOSE TO EARTH

All early peoples seem to have believed in the existence of a solid sky which they felt to be necessary because the stars could not stand alone. They could not understand how these brilliant points of light could appear in the same relative position night after night unless they were securely fastened to something solid. In no other way could they account for the fact that the different constellations, which played such an important part in their myths and legends, retained their shape for generations.

No one questioned the existence of the crystal firmament and one of the early philosophers actually taught that thunder was caused by the winds breaking through the solid firmament that was above the earth. Another considered the solid firmament necessary in order to hold the water that was used to cool the earth's axis of rotation. These ideas were not confined to primitive peoples for even as late as the middle of the sixteenth century the idea of a solid sky was widespread.

In the opinion of Aristotle, and many of the other philosophers, the heavens were not far from the earth, heaven being the upper story and the earth the ground floor. There have developed throughout the ages many myths and legends that have to do with ascensions into heaven and descents from heaven. Among these legends may be mentioned the story of Jack and

the Bean Stalk, Jupiter and Ganymede, and many others. Mortals were caught up into heaven, angels flew back and forth, Jupiter and Thor hurled their thunderbolts down upon the earth, and heathen gods became interested in earthly affairs and came down from heaven on all sorts of errands.

In order that he might convey some idea as to the enormous distance from the earth to the sky Hesiod said that an anvil required nine days to fall from heaven to earth; but Milton seemed to feel that heaven was much closer since he allowed only one day for Vulcan's fall. As a matter of fact, a ray of light, traveling with a speed which would take it seven times around the earth in one second, requires more than four years to come from the nearest star to the earth and there are not more than 125 stars that are known to be close enough to the earth for their light to reach us in thirty-three years.

THE PRIMITIVE UNIVERSE HAS BEEN EXPANDED BY SCIENCE

One by one the ideas of primitive man with reference to the earth and the heavenly bodies have changed as a result of scientific research until we now have an entirely different outlook upon our universe. We have learned that the earth is not flat; it is round. The earth is not held up by pillars or supports of any kind; it is suspended in space by the invisible chains of gravitation. The earth is not the center of the universe; it is a very small planet revolving around a very small sun. Stars are not small lanterns moved by angels; they are gigantic suns each of which is moving with an enormous velocity. Perhaps after all the universe was not created for the benefit of man, but man has spent millions of years trying to adapt himself to his environment as he finds it. What a loss of dignity! What a gain in grandeur!

The sky is not solid. From the modern point of view it does not exist at all. The earth seems to be surrounded by what we call the Celestial Sphere on which are to be found the sun, moon, stars and all other heavenly bodies at apparently the same distance from the earth. This is of course merely the effect of the optical projection of these celestial objects into empty space.

The Celestial Sphere is the same sphere for inhabitants of other worlds, but the stars as viewed from these other worlds would be projected into different positions than those in which we see them. That conspicuous northern constellation, the Big Dipper, would not in any way resemble that instrument if we could study it from some position far removed from the earth. Because of our annual motion around the sun that heavenly body is daily projected into a new position on the Celestial Sphere so that it appears to make a complete circuit of the sky during the course of a year. The moon is so close to us that its position among the stars at any given instant is different for two observers on opposite sides of the earth.

When the researches of astronomers had made it evident that the Celestial Sphere is, shall we say, an optical illusion, they supplied the answer to the troublesome questions: "Is the sky solid? Is it liquid, or is it gaseous?" It does not exist at all.

THE HUMAN BRAIN CANNOT APPRECIATE THE SIZE OF THE UNIVERSE

Here we stand upon this little ball called the earth and look out into the universe around us. Little do we realize that, as we make our majestic swing around the sun each year, we are covering only an infinitesimal part of space. Although the invisible gravitational chain with which our world is tied to the sun is of sufficient length—93 million miles—to enable us to explore quite a bit of the universe when measured in ordinary earthly units, this chain will have to be stretched 275,000 times if we ever visit the nearest star.

We have learned that the sun is many, many times as large as the earth. In fact its dimensions are so great that, if it were hollowed out into a shell and the earth were placed at the center of it, there would be plenty of room inside of the shell for the moon to make its monthly trip around the earth. Indeed it is very difficult to imagine an object so large. We have also discovered that the sun spots and the prominences which so frequently shoot out from the edge of the sun are many times as large as the earth, so that we are perhaps wondering whether the sun is not the largest body in the universe. By no means, for the astron-

omers tell us that every star in the sky is a sun and that our sun is nothing but a star. It appears to us to be very large merely because we are close to it, but as a matter of fact it is a very small star.

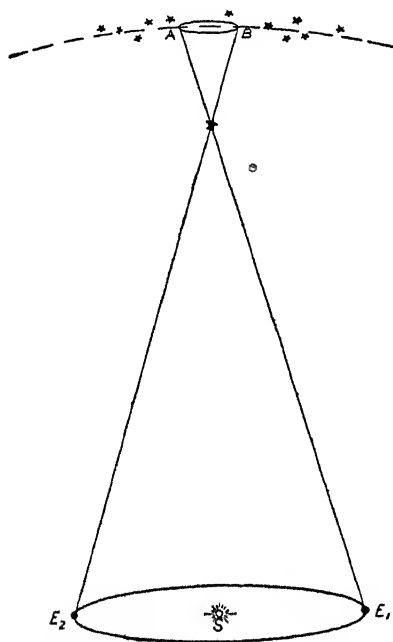
Stars are not tiny points of light as they seem to be, nor jewels on a crystalline sphere, nor lanterns held by angels as early peoples often supposed, but they are actually giant suns whose volumes average a million times greater than the volume of the earth and which shine by their own light. Aldebaran looks like Mars, but how different! If someone should throw a blanket over the sun some night while Mars and Aldebaran were shining in the sky, Mars would disappear immediately because it shines only by reflecting the light of the sun, while Aldebaran and all of the other stars would continue to shine as before. Stars appear as points of light simply because of their immense distances from us, which average many millions of times the distance from the sun to the earth.

THE STARS ARE AT AN ENORMOUS DISTANCE FROM THE EARTH

As we drive down our highways in our automobiles the telephone poles rush by us very rapidly. If we look over into the fields at the farm houses we discover that they also appear to be moving, although not quite so rapidly. A glance at the distant mountains reveals the fact that they are also apparently in motion, but the moon and other heavenly bodies near the horizon appear to move along with us. Of course we know that these objects are really not in motion but that their apparent motion is due to the fact that we ourselves are moving, the apparent motion being more rapid the nearer the object is to us.

Let us now consider another motion of which we all unconsciously partake. We are passengers on an earth that is speeding down the highway of space at the rate of nineteen miles a second on its annual journey around the sun. In July we are 186 million miles from where we were in January, yet the stars do not appear to have changed their positions. This fact was cited by one of the early philosophers in order to con-

vince his followers that the earth was fixed in space. "Surely," said he, "if we are moving around the sun every star in the sky would appear to be moving in a little orbit with a period of one year. The stars have no such motion and, therefore, the earth is fixed in space." This is a very logical argument, but unfortunately the philosopher's assumption that the stars were fixed in space turned out to be far from the truth.



If we look at the same star in June and December from the two ends of a "base line" 186 million miles long, we do not realize that the star has moved unless we use a telescope. How enormous must be the distance to the stars!

Every star in the sky actually has this apparent motion, due to our annual trip around the sun, but it cannot be detected by the naked eye. The stars must, therefore, be very far from the earth. They must also be very large or we could not see them at that great distance. If the sun were as large as Neptune's orbit, it would appear as a small luminous point when viewed from the nearest star.

The light from most stars does not reach us for more than a hundred years. Those in the Milky Way are several thousand years off. What are they like now? Surely, the earth is a ship on the infinite sea of space, the members of the human race are her passengers and eternity is her port.

THE NEAREST STAR IS THIRTY MILLION MILLION MILES AWAY

Slip on the wings of your imagination and fly with me with the speed of a radio wave out into the unknown depths of space. We will pass the moon in two seconds, we will reach the sun in eight minutes, but it will be four hours before we come to the orbit of Neptune at the outskirts of the sun's domain. We will then sail on and on with a speed of 186,000 miles per second for more than four years before we reach the first star. The

MOON ———	1½ seconds	VEGA ———	26 years
SUN ———	8 minutes	POLLUX ———	32 years
NEPTUNE —	4 hours	ARCTURUS —	40 years
NEAREST STAR —	4½ years	CAPELLA —	49 years
SIRIUS ———	9 years	ALDEBARAN —	57 years
PROCYON ———	11 years	REGULUS —	57 years
ALTAIR ———	16 years	ACHERNAR —	73 years
FOMALHAUT —	25 years	ORION ———	600 years

A radio message from the earth would reach our nearest neighbors after the time intervals shown above.

distance to this star when expressed in ordinary terrestrial units is thirty million million miles, a number which has absolutely no meaning to us.

On account of the enormous distance to the stars we must use a new unit of measure in order that our results may have some meaning to us. For convenience we choose as a unit the distance light travels in one year, which we call the Light Year. When expressed in ordinary units the Light Year is equivalent to six million million miles. Some of these distances are almost beyond human comprehension. It is a little difficult to realize as we look tonight at the nearest star in the sky that the light by which we

see this star left it more than four years ago and, so far as we now know, that particular star might have vanished from the sky four years ago and we would still see it shining in its appointed place.

The seven stars that form the Big Dipper are about seventy or eighty light-years away, the beautiful Southern Cross is 200 light-years from us, the Pleiades are shining down upon us from a distance of 220 light-years, Perseus is between 300 and 400 light-years from us, and the stars in Orion are from 500 to 600 light-years from our sun.

When we realize the enormous distance which separates us from the stars we recall the words of Thomas Hood:

I remember, I remember, the fir trees straight and high
And how I thought their slender tops were close against the sky;
It was a childish fantasy, but now 'tis little joy,
To know I'm farther off from Heaven than when I was a boy.

STARS DIFFER IN COLOR AND IN TEMPERATURE

The stars are not merely points of light in the distant sky but every star is a sun, comparable in size to our own sun but thousands, and in most cases millions, of times as far away. Much time has been devoted to stellar astronomy during the last few decades and the astronomers at Harvard Observatory have recently brought out a catalogue in which 225,000 different stars are classified according to the chemical elements which they contain. The temperature of a star is assumed to depend upon its chemical composition and many stars are hotter than the sun.

According to the Harvard classification a very few stars have temperatures of about 30,000 degrees Centigrade, a few more about 20,000 degrees, and a large number about 10,000 degrees. Sirius is an example of the third class. About ten per cent have a temperature of about 8000 degrees, like Canopus and Procyon, and about twenty per cent, including Capella and our sun, have a surface temperature of the order of 6000 degrees. The most numerous class, which contains Arcturus and Aldebaran, have temperatures of about 4000 degrees and a very small

group, containing Betelgeuse and Antares, have a still lower temperature.

Many stars are white or bluish-white, like Sirius, Regulus, Rigel and Vega. Others are yellow, like Arcturus, Fomalhaut, and Capella, and still others are red like Aldebaran, Antares, and Betelgeuse. This contrast in colors may be very easily noticed on any winter evening by looking at the red Betelgeuse and the bluish-white Rigel in Orion, and then at the yellow Capella. In general the white stars are supposed to be the hottest, the yellow stars like our sun not quite so hot, and the red stars the coolest of all.

*WHITE STARS - Sirius, Regulus,
Rigel, Vega.
YELLOW STARS- Arcturus,
Fomalhaut, Capella
RED STARS - Aldebaran
Antares, Betelgeuse*

STARS DIFFER IN COLOR

It was at one time thought that the color of a star, which is an indication of its temperature, depended upon its age. That is, the blue stars were comparatively young, the yellow stars had reached middle age, and the red ones were extremely old. Recent researches, however, lead us to believe that this supposition is not quite correct. Nevertheless, everything in the universe is gradually changing and the stars are not exceptions to this general rule. Some stars are young, others are in the prime of life and still others apparently have fulfilled their mission and will soon be mere dark bodies in space, invisible until they collide with some other star.

PTOLEMY DIVIDED STARS INTO SIX MAGNITUDES

The apparent brightness of a star is called its "magnitude" and refers simply to its brightness as observed from the earth and

has nothing to do with its size or its luminosity. Hipparchus and Ptolemy divided the visible stars into six magnitudes, those of the sixth magnitude being the faintest visible to the eye. The stars of the first magnitude, in descending order of brightness, are: Sirius, Canopus, Alpha Centauri, Vega, Capella, Arcturus, Rigel, Procyon, Achernar, Beta Centauri, Betelgeuse, Altair, Alpha Crucis, Aldebaran, Pollux, Spica, Antares, Fomalhaut, Deneb and Regulus.

Some of the stars of the second magnitude are: Polaris (the North Star), Hamal (at the eastern end of the triangle in Aries), Castor (in Gemini), Alphard (the heart of Hydra), the three stars in the Belt of Orion, Algol (in Perseus) and the seven stars in the Big Dipper.

This arbitrary division of all naked eye stars into six magnitudes does not of course take care of the fainter stars that were discovered after the invention of the telescope. These stars are now classified according to the same scale and we have stars of the seventh, eighth, ninth, and fainter magnitudes. It is said that with the 100-inch telescope at Mt. Wilson Observatory stars as faint as the twenty-first magnitude can be recorded by photography. Such stars are a hundred million times fainter than those of the first magnitude.

By means of instruments recently invented it has been possible to assign precise values to the brightness of a star and we have found that Sirius and several other bright stars are actually brighter than the first magnitude. The planets Jupiter, Venus, Mercury, and Mars are sometimes brighter than the stars so that, if we wish to assign a precise value to the brightness of one of these planets, we must use negative numbers.

A star of the first magnitude is just one magnitude brighter than a star of the second magnitude so that a star of 0 magnitude would be one magnitude brighter than a star of the first magnitude. There would be the same difference in brightness between a star of -1 magnitude and 0 magnitude. On this scale we say that the magnitude of Rigel is 0.3, and that Canopus and Sirius are stars of magnitudes -0.9 and -1.2 , respectively. On the same scale the magnitude of Venus may sometimes reach -4.3 , while that of the full moon is -12.5 and the magnitude of the sun is -26.7 .

THE NEAREST STARS ARE NOT THE BRIGHTEST ONES

The difference in apparent brightness of stars is due partly to their actual luminosities and partly to their distances from us. Many stars are hundreds and even thousands of times as bright as the sun. Among these we may mention Sirius, Capella, Arcturus, Betelgeuse, Deneb, Canopus, Antares and Rigel, the last four of which seem to be super-suns, about 14,000 times as luminous as our sun. As a rule the blue and bluish-white stars are more luminous than the red ones.

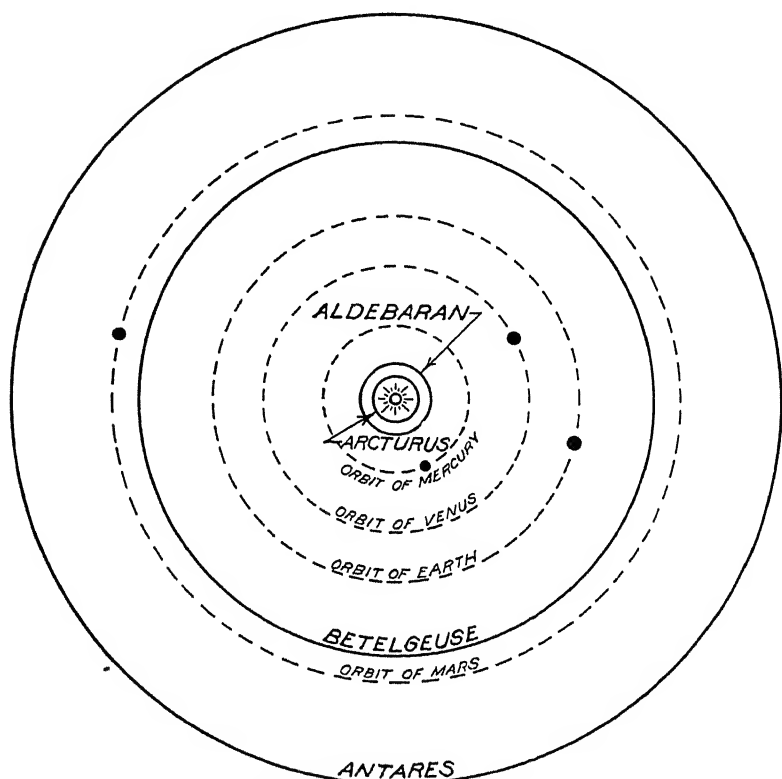
It is obvious that the apparent brightness of a star tells us very little about its distance for only two of the six stars closest to the earth—Alpha Centauri and Sirius—are bright enough to be visible to the naked eye. Our nearest neighbor—Proxima Centauri—is visible only through a large telescope but it is not half as far away as Sirius, apparently the brightest of all the stars.

It is only recently that we have been able to actually measure the diameters of stars. The first one to be measured was Betelgeuse in Orion and it was found that this star has a diameter about 300 times as great as that of the sun. If Betelgeuse were hollowed out in the form of a shell and the sun were placed at the center, Mercury, Venus and the earth would be inside the star. Since Betelgeuse is 1,000 times as bright as the sun we are fortunate in that nature has not placed this giant star nearer the earth than 200 light-years.

Up to the present time only seven stars have been measured and the smallest of these, Arcturus, is about twenty-seven times as large as the sun. The largest known star is Antares in Scorpio whose diameter is at least 450 times that of the sun. It seems then that we are not only living on a very small world but we are associated with a sun that is rather insignificant in comparison with the other suns in the universe.

Alpha Centauri, until recently considered to be our nearest neighbor, is about the same size as the sun and only four and one-third years away. It has about the same mass and gives about the same amount of light and heat. In fact, it seems that our sun

has a twin brother in the southern sky that remains forever invisible to those who live north of latitude thirty degrees.



Arcturus and Aldebaran are somewhat larger than the sun. Betelgeuse is almost as large as the orbit of Mars and Antares is still larger.

MAN IS NOW ACQUAINTED WITH MANY INDIVIDUAL STARS

The nearest naked eye star ordinarily seen from the northern hemisphere happens to be also the brightest of all the stars, except the sun. This is Sirius, the "dog star," which regulated the calendar of ancient Egyptians. Sirius is about three times as heavy as the sun and is at a distance of 9 light-years which means that, as we look at this star, we see it not as it is today but as it was nine years ago. Although Sirius would appear

about twenty-seven times as brilliant as the sun if both could be looked at from an equal distance, it is really not a brilliant star. It appears very bright to us principally on account of its relative nearness.

The southern star Canopus is 14,000 times as bright as the sun but its enormous distance (650 years) from the earth reduces this brightness to that of an ordinary first magnitude star. The bright blue star Vega in Lyra, which is about fifty times as bright as the sun, is approximately thirty years from the earth. Capella in Auriga is 200 times as bright as the sun and throws its yellow rays toward us across a space of about fifty light-years.

Arcturus, the Bear-keeper, has a diameter about twenty-seven times the diameter of the sun and is about 100 times as bright. Most of its brightness, however, is lost to us because its rays of light only reach us after having spent forty years on their journey through space.

Rigel in Orion is more than ten times as bright as Betelgeuse. This difference is not so obvious to us because Rigel is at least 500 years away. Near Sirius is the bright star Procyon which is almost six times as bright as the sun and at a distance of eleven years.

In Aquila we find another bright star Altair from which light can reach the earth only after having spent about sixty years on the way. Altair is nine times as bright as the sun. Aldebaran in Taurus has a diameter forty times as great as that of the sun and is ninety times as bright. Its distance is about fifty-seven light-years. The giant Antares is 14,000 times as bright as the sun and has a diameter 450 times as great but it appears no brighter than Spica because of its enormous distance (450 light-years).

STARS DIFFER IN CHEMICAL COMPOSITION

After the invention of the spectroscope in 1860 scientists began to study the composition of the sun and soon made the remarkable discovery that this celestial furnace, which furnishes us light and heat and governs the motions of all the planets, con-

tains the same chemical elements that we find on the earth beneath our feet. Our chemists are now familiar with ninety-two elements, beginning with hydrogen with its single revolving electron and ending with uranium with ninety-two electrons. Of these elements fifty have been found on the sun, and not a single *new* element.

Much attention has recently been given to the constitution of the stars. It is a well known fact that every star is a sun, so that we may expect to find in the stars only those chemical elements that exist in the atmosphere of the sun. No two stars seem to be exactly alike in composition, for every star has a spectrum of its own—its fingerprint if you please—when studied with the spectroscope. Nevertheless, in general, we may say that those elements that are most abundant in the sun also exist in large quantities in the distant stars.

The study of the constitution of the stars is a very fascinating one for many baffling problems present themselves. Stars are merely masses of intensely hot gas like the sun, but they vary in temperature to such an extent that it is convenient to divide them into about seven distinct classes, beginning with those stars that are about six times as hot as the sun and ending with those whose surface temperature is only about half of that of the sun. When gases are subjected to temperature and atmospheric pressure so different from that with which we are familiar, is it any wonder that they “misbehave” and become very difficult to identify?

We know the size of a star and the total mass within it. We can identify certain chemical elements in its atmosphere but the portion of the star that is accessible to direct observation is but a very small fraction of the whole. Will we ever be able to penetrate beneath the surface and study the interior of a star? Until very recently this question was answered by an emphatic “no,” but our present knowledge of the composition and properties of atoms make us hopeful of a solution of this problem in the near future.

MANY STARS ARE DOUBLE SUNS

When a powerful telescope is turned on a star we are frequently surprised to discover that what appears to the naked eye to be a single star is really a group of two or more stars at such a remote distance that the human eye cannot separate them. These objects are called double stars, triple stars, quadruple stars, etc. Some double stars are merely optically double; that is, they lie almost in a straight line as viewed from the earth and really have no connection with one another. On the other hand, many stars are physically double; that is, they are actually bound together by gravitational attraction and are revolving slowly about their common center of gravity. This is also true of triple stars and of groups containing four or more stars.

Among the well known bright stars that are double we may mention Sirius, Alpha Centauri, Rigel, Procyon, Alpha Crucis, Aldebaran, Antares, Capella and Castor. One of the most interesting double stars is Mizar, the middle star in the handle of the Big Dipper, whose faint companion, Alcor, was recognized by the Arabs at least a thousand years ago. In 1650 Mizar itself was found to be a telescopic double—the first double to be discovered with a telescope—and one of its components is now known to consist of two parts that are so close together that the telescope will not separate them.

In 1779 Sir William Herschel began his systematic study of the sky and within five years discovered about 700 double stars. Since his time this work has been carried on very vigorously by means of photography until today we recognize about 18,000 pairs of stars. Of the stars visible to the unaided eye about one in every nine is double. A series of photographs of a double star taken at intervals of several months will reveal the motion of the two parts of the star around the center of gravity. By a careful study of this motion the mathematicians are able to compute the mass of the double star.

An interesting question arises with reference to the kind of time used by people who live on worlds revolving about a double sun. It would be necessary to have a definite understanding as to which one of the two suns was to be used for measuring time for both suns might be shining in different parts of the sky.

BOTH DOG STARS HAVE SMALL COMPANIONS

Sirius is not only the brightest of all the stars except the sun but it has another distinction in that it has a very close companion made of material more dense than anything on the earth. This "companion of Sirius" was detected almost one hundred years ago by the fact that something was causing Sirius to move in an irregular path which could only be explained on the supposition that the "Dog Star" was accompanied by a companion which was so faint that the astronomers had not yet been able to see it. The actual discovery of the companion of Sirius was made by an American, Alvan Clark, Jr., in 1862. Mr. Clark was not an astronomer at all but a maker of telescopes who was testing a new lens by studying the brightest star in the sky.

Sirius and its companion revolve about their center of gravity making one complete revolution in about fifty years. The diameter of the companion is so small and its mass is so great that its density is inconceivably great. A pint of lead weighs about eleven and a half pounds, a pint of mercury about fourteen pounds, but if we could obtain a pint of the material of which the companion of Sirius is made, we would find that it would weigh about twenty-five tons.

Imagine material 50,000 times as dense as water. What kind of substance could average a ton to the cubic inch? The general public, and some astronomers, were skeptical until Dr. Barnard at Yerkes Observatory found another heavy dwarf star and Dr. Van Maanen at Mount Wilson discovered a third which weighs seven tons to the cubic inch. These heavy stars are all in the immediate vicinity of the earth. Barnard's star is only six light-years from us, Sirius is not quite nine, and the gap between us and Van Maanen's star can be traversed by a ray of light in about thirteen years.

Procyon, the bright star in the Lesser Dog, also has a dense companion, its period of revolution being about forty years. The North Star, Polaris, has two companions and so has Alpha Centauri, the closest bright star to the earth. We might mention many other stars which, to the naked eye, appear to be single points of light but which by means of the telescope can be separated into two or more suns.

MANY BINARIES CANNOT BE SEPARATED BY TELESCOPES

Much time is now being devoted to the study of binary stars—those that actually revolve about a common center of gravity. There are many binary stars that are so close together and so far from the earth that even the most powerful telescope will not separate them. However, the dual character of these stars becomes evident when we make use of the spectroscope and the interferometer. A recent study of Capella in Auriga shows that this star is really made up of two suns revolving about their center of gravity with a period of about 104 days, although we do not have a telescope of sufficient power to break it into two parts. Both of the bright stars in Orion are spectroscopic binaries. The two component parts of Betelgeuse revolve about their common center in about 6 years, and those of Rigel have a much shorter period which has not yet been determined.

One of the most famous binary stars is Castor, the fainter of the Twins. Even a small telescope will reveal Castor as a double star, one part being of the second magnitude and the other of the third. These two suns move more slowly than Capella because they are farther apart and they take about 300 years to make one revolution about each other. However, it is interesting to study Castor through the spectroscope for it reveals many things about this beautiful star that are not apparent through the telescope.

Each component part of Castor is itself a spectroscopic binary star like Capella and near the center of the system is a very faint star which is also a spectroscopic double. Surely things are not always what they seem. To the naked eye Castor appears to be a single sun radiating light from the depths of space when as a matter of fact it consists of six separate suns all revolving around each other in a most complicated fashion.

How can we explain the existence of a double, a triple or a multiple star? Did a single star break up into several stars or did one star capture another as it happened to pass by? Both of these questions have been studied recently and, although the first theory for a time seemed quite reasonable because of the rapid rotation of some of the stars, the difficulties in the way of both

theories are so great that a definite answer to our questions will probably not be given for many years to come.

THE FIXED STARS ARE REALLY DASHING ABOUT IN ALL DIRECTIONS

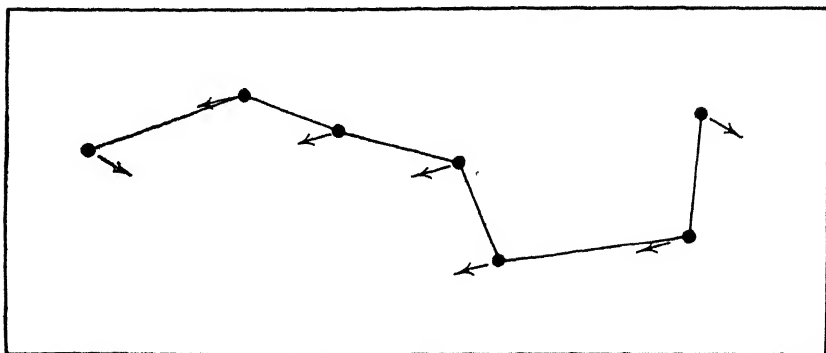
The heavenly bodies which revolve about the sun are called planets (wanderers) because they change their positions in the sky, and for a long time it was believed that the stars had no such motion. Of course all of the stars seem to be in motion but this apparent motion is due to the rotation of the earth and does not in any way affect the relative positions of the stars.

Since star-groups and constellations remain unchanged for long periods of time we are in the habit of speaking of the "fixed" stars, when they are not fixed at all but are continually changing their positions with reference to each other. In fact if there is anything in the entire universe that is not in motion the astronomers have not yet discovered it.

Stars are said to be "fixed" because they are so far away that neither the motions of the earth and the sun nor those of the stars themselves have an appreciable effect upon their apparent positions. Halley, in 1718, was the first to demonstrate that the stars are not fixed and now every school boy knows that all stars are actually moving at random in orbits that appear to be straight lines, so that all constellations will gradually change their shapes. The Dig Dipper will not resemble a dipper very long because the star in the end of the handle and one of the stars in the bowl are moving in one direction while the other five are moving in almost the opposite direction.

The red Betelgeuse is receding from the earth at the rate of 13 miles a second and Rigel is also receding about 14 miles a second, but the fastest moving bright star is Arcturus which has a velocity of about seventy-five miles a second. This would take it around the earth at the equator in five minutes. It is difficult to appreciate the rapid motion of Arcturus on account of its great distance, but during the past 800 years this bright star has moved southward by an amount approximately equal to the apparent diameter of the moon. "Canst thou guide Arcturus?" asks Jeho-

vah in Job (38:32). This is not merely a query as to whether Job can guide a star, but Jehovah is calling Job's attention to the fact that Arcturus is the fastest moving bright star—a fact which we have discovered only recently.



Because of the motion of its individual stars, the Big Dipper will get out of shape in due time.

OUR DAY-STAR, THE SUN, IS ALSO MOVING

If all of the stars are in motion, in random directions and with different speeds, then how about the sun? If the sun itself is merely a star, as the astronomers assure us, then certainly the sun must be in motion and if the sun is moving then it must be carrying the entire solar system with it. This is indeed a very fascinating problem, but one that could be solved only by an expert practical astronomer after many careful measurements with good optical aid. And who could have been found that was better fitted for this task than Sir William Herschel, who had passed in review the entire visible heavens with the best telescope available in his day?

Early in the nineteenth century Sir William attacked this problem. He realized that if the sun and the earth were moving toward a certain point in the sky, the stars in this part of the heavens must be getting closer to us so that after a few years they should appear to be farther apart. Likewise those in the opposite part of the heavens should appear to be closer together. Soon Sir William pointed out the exact place in the sky toward

which the sun is moving—the “apex” of the sun’s way. This point is not very far from the position occupied by the bright star Vega at the present time. The sun is moving toward Vega at the rate of about 63,000 feet a second. Compare this speed with the velocity of a cannon ball which is approximately 3000 feet a second. Imagine a projectile 332,000 times as heavy as the earth flying through space with a speed twenty-one times that of a cannon ball! Such a tremendous amount of energy cannot be appreciated by mortal man.

At this point it may be well to call attention to some of the motions of the earth. We go about our daily affairs unmindful of the fact that the little ball upon which we live is spinning on its axis very rapidly, revolving around the sun with a speed of eighteen and one-half miles per second, and at the same time following the sun in its headlong plunge through space. Every time the clock ticks the solar system is about twelve miles closer to Vega. Of course Vega is also moving so that we need not be afraid of a collision.

TEMPORARY STARS RESULT FROM COLLISIONS

Imagine millions of suns dashing about in all directions with terrific speed. Some day collisions must occur. We then witness the birth of a Nova, a new sun. If one sun does not collide directly with another it is sure sooner or later to pass through a resisting medium where its luminosity will be increased by friction. Recent photographic studies have shown that Novas are really not new stars at all but that they were faintly visible as telescopic stars before their increased brightness. For this reason the term “temporary stars” is more accurate than “new stars.”

The brightest stars have been Novas. The Chinese annals tell of a Nova in 134 B. C. that was plainly visible in the day time. This is the one that induced Hipparchus to make his star catalogue so that such temporary stars might be more easily detected. Among those Novas that have been visible in the day time were Tycho’s Star in 1572, Kepler’s Star in 1604 and Nova Aquilae in 1918, which blazed out at the time of the total solar eclipse on the eighth of June. We have records of eighty bright temporary

stars during the past three centuries, sixty of which have appeared during the last thirty years.

Most temporary stars appear very close to the Milky Way or in the spiral nebulas that are outside of our galaxy. They reach their brightness very rapidly and fade very slowly, changing to a yellowish color as they fade. The "Blaze Star," which appeared in 1866, increased in brightness so rapidly that it rose from invisibility to a star of the second magnitude in six hours. The "exploding star" which appeared in Hercules and not far from Vega in 1934 reached its maximum brightness (first magnitude) on December 22nd and then quickly faded away.

Every temporary star brings us a message of some celestial catastrophe that occurred, not today, but many, many years ago. The bright rays of light as they came from the Nova in Perseus in 1901 informed us that two suns had met and a new sun was born more than three centuries before, when Elizabeth was Queen of England and America was a wilderness. In the face of such evidence we wonder whether cosmic life has either beginning or end. Suns gradually contract and planets are formed about them. When these hot planets become cool enough to have a stable crust life appears and continues to develop until the sun around which the planet is moving collides with another sun and a new sun is formed. Who can find the beginning or the ending of cosmic life?

SOME STARS VARY IN BRIGHTNESS FROM TIME TO TIME

A study of the brightness of stars led to the remarkable discovery that there are about 6000 stars whose brightness is not constant but varies from time to time. These are called "variable stars" and more and more stars are annually being added to this list.

In some cases the brightness of a star will remain practically stationary for some time and then will decrease rapidly to a minimum. After remaining constant at the minimum brightness for a certain length of time the brightness will increase to normal very rapidly. We call these stars eclipsing variables because we believe that the change in brightness is due to the fact that the

star is really double and composed of a dim star revolving around a brighter one. Every time the fainter star passes in front of the brighter, the light from the binary system decreases.

The eclipse of one of the components of a binary star by the other is of course not visible to us unless the solar system is approximately in the same plane in which the two stars are moving and it would indeed be very remarkable if many double stars were so oriented. Only a small fraction (about 300) of the many thousand known double stars are eclipsing variables, the most famous of which is Algol, the winking "Demon Star" in Perseus, whose variability was discovered in 1670. Surely no better place could be found for a winking star than in the evil eye of Medusa who was destroyed by Perseus because one look into her face meant death to any mortal.

There are other stars whose brightness varies more or less uniformly but not in the manner just mentioned. About 200 of these belong to a class known as Cepheid variables with short periods ranging from approximately a day to about a month. Although the light from these stars does not go on and off suddenly as in the case of the eclipsing variables, their luminosity is distinctly periodic. The Cepheid variables have been very useful in determining the dimensions of the galaxy in which we live and our distance from other galaxies. Other variable stars have longer periods of from five months to two years and there are still others whose brightness—so far as we have yet been able to determine—does not vary periodically. Of course temporary stars which blaze out and then rapidly fade away may also be classed as variables.

ABOUT 350 OPEN STAR CLUSTERS SURROUND THE SOLAR SYSTEM

In addition to individual stars, some of which have been found to be double, triple, or even quadruple, there are several hundred "star clusters" in the sky. Just as the wild ducks at certain seasons of the year find it to their advantage to come together in flocks and migrate from one part of the earth to another, all moving in the same direction with the same speed, so

also do the stars move in clusters from one part of space to another. Where are they going and when will they return? Of course the human race is too young to answer these questions but we have discovered that there are "open" clusters like the Pleiades and the Hyades and "globular" clusters like the famous clusters in Centaurus and Hercules, the only ones of this type visible to the naked eye.

The open clusters—of which there are about 350—are in the immediate vicinity of the earth so that the individual stars, all of which are moving in the same direction, appear to be rather far apart. Five stars in the Big Dipper (all but the two end stars), the brightest star in the Northern Crown, one of the bright stars in the Charioteer, the brilliant Sirius and about thirty other stars form the Ursa Major (Great Bear) Cluster. This cluster is now passing by our sun and its retinue of worlds. We are at the present time inside of the Great Bear cluster but we do not belong to it. Because of our central position these stars now appear to be projected upon widely separated parts of the sky but very soon, astronomically speaking, this cluster will pass us by and will recede to such a distance that it will form a compact group of stars like the Pleiades.

The Hyades, in Taurus, passed the sun less than a million years ago. This cluster is now about 120 light-years away and is destined to become a telescopic object in Orion. The Pleiades are about 220 light-years from the earth and are easily visible without optical aid. The Coma Berenices Cluster, which to the naked eye looks like a cob-web, is at a distance of about 260 light-years. A little farther away are the Beehive Cluster in Cancer and the famous Double Cluster in Perseus, which an ordinary field glass will separate into individual stars.

GLOBULAR CLUSTERS ARE BALLS OF STARS

The 350 open star-clusters are relatively near the earth but the 93 globular clusters that have been discovered up to the present time are so far away that the largest telescope is not able to entirely separate them into their component stars. While the open clusters usually contain less than a hundred stars, and in very rare cases only a few thousand, globular clusters are

immense balls of stars tens and even hundreds of thousand in number.

It is only recently that we have been able to determine the distance from the earth to some of the globular clusters. This was accomplished for the most part by Dr. Shapley of Harvard



A star cluster in Hercules.—Yerkes Observatory.

Observatory. We now find that their distances vary from 20,000 to 200,000 light-years, so that some of them must compare very favorably in size with our own galaxy. The cluster in Centaurus and the Great Cluster in Hercules may not exist now because they are at such a distance from the earth that our telescopes are now bringing us information about what was happening on the first cluster about twenty-two thousand, and on the second cluster about thirty-three thousand, years ago when our human race was in its babyhood. The Great Cluster in Hercules is composed of at least forty thousand separate suns which may be counted and probably many million more, no two of which are perhaps within a million miles of each other. Through the telescope it has the appearance of a "Chrysanthemum of Stars."

When Edmund Halley discovered these two famous globular

clusters in 1677 and 1714 he realized that here were two objects that were perhaps much larger than stars, but he seems to have had no suspicion as to their real dimensions. When we attempt to visualize their dimensions and their distance from the earth the human mind staggers.

The improvement of the sensitive plate has made possible the discovery of many clusters by photography and we have recently added several double clusters to our list. Truly we are living in the age of miracles. Thousands of years ago these stars sent out waves of light which were radiated into space in every direction. Most of this energy was wasted but some of the waves are caught by our telescopes and beat for several hours upon the sensitive plates. Thus do we obtain the autograph of unnumbered suns millions of millions of miles away.

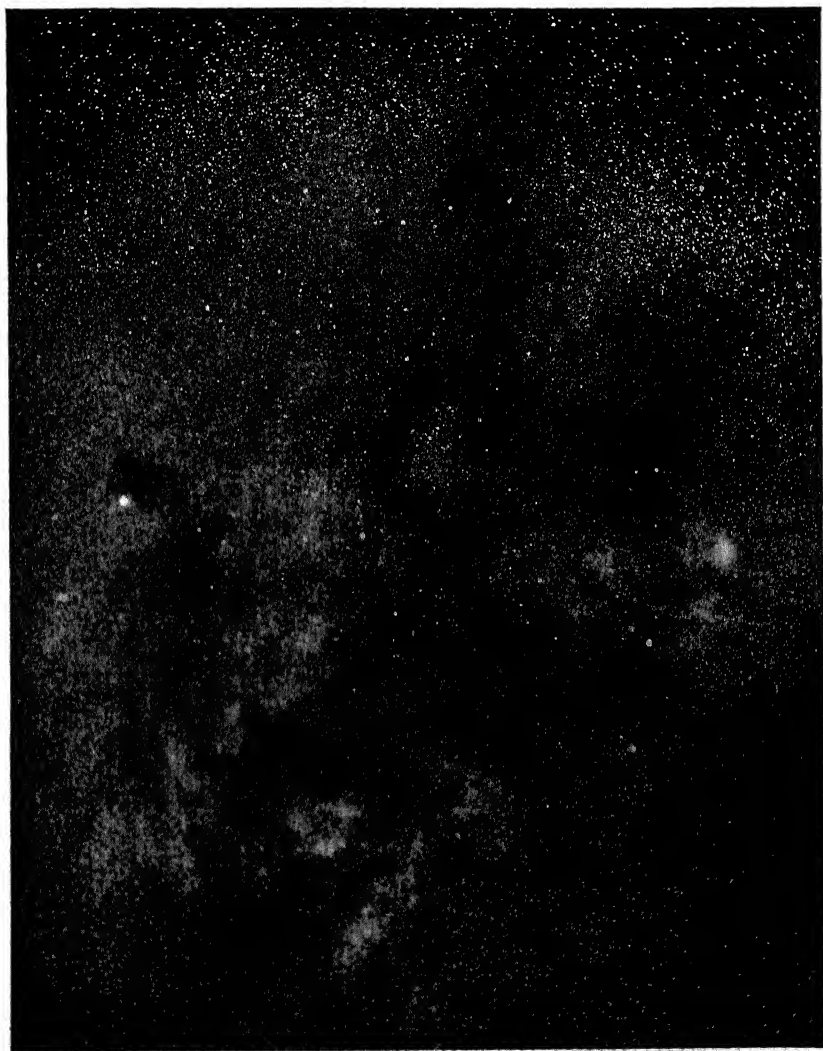
THE VISIBLE STARS NUMBER ABOUT 5,000

How many stars are in the sky? The visible stars have often been supposed to be countless, but as a matter of fact it would be an easy matter to count all of the points of light which are visible to the naked eye. The oldest star catalogue that we possess was prepared by Ptolemy and contains 1025 stars. Unfortunately a much older catalogue which was the work of Hipparchus has been lost. If you study the heavens from a position where the horizon is not obstructed in any direction and at a time when there are no clouds in the sky and no moon or artificial lights to interfere with your vision, you will be able to see only about 2000 stars at any one time.

Of course there are some stars that never set and others that never rise so that if you should move about from one latitude to another you would continually see a new set of stars. If, however, you make your observations from different parts of the earth and at different times of the year the total number of stars that you can see without optical aid is about 5000. This includes all of the stars brighter than the seventh magnitude. The average person can count ten stars inside the bowl of the Big Dipper. Test your eyesight by counting them yourself.

We must not get the idea that there are only a few thousand stars in the sky for the sensitive plate reveals countless millions.

It is estimated that about fifty billion different stars are visible at one time and place through our largest telescopes, and that there are about twenty times as many stars in the entire sky as there are human beings on the earth. The first systematic star-count through a telescope was made by Sir William Herschel near the end of the eighteenth century and his son, John, continued this study into the southern heavens.



The Milky Way north of Ophiuchus. Every point of light represents an individual star.—Yerkes Observatory.

The stars are not uniformly distributed in the sky. In some parts of the heavens they are very scarce while in the region of the Milky Way they are so numerous that the telescope can hardly separate them. The number of stars in an average area the apparent size of the full moon is about 200,000 and the average area the size of the bowl of the Big Dipper contains about fifty million stars when examined by our most powerful telescopes.

BRIGHT NEBULAS ARE MASSES OF LUMINOUS GAS

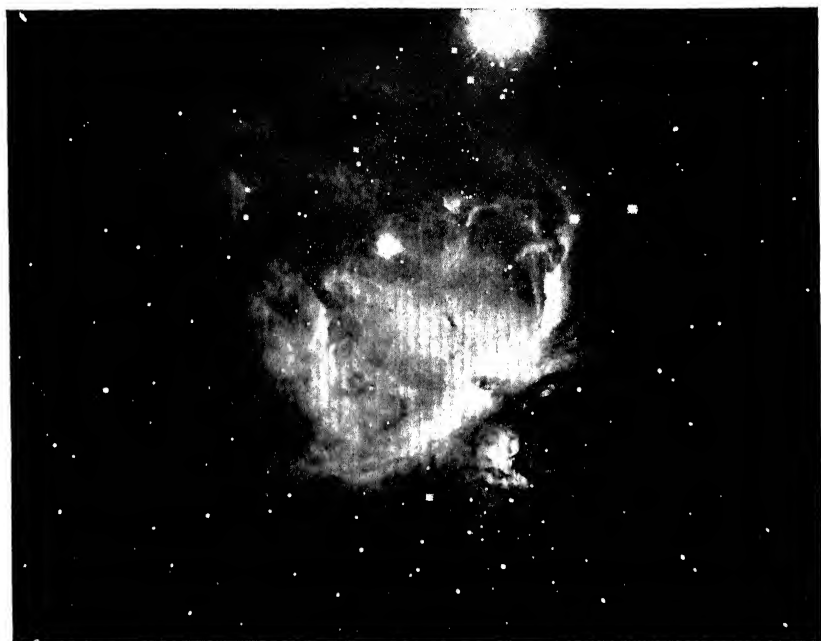
If you will look very closely at the middle star in the Sword of Orion you can easily see a hazy patch of light somewhat resembling a luminous cloud in the heavens. In the constellation Andromeda can be seen another patch of light resembling an oval-shaped luminous cloud about six times the apparent size of the full moon. The telescope reveals many such luminous clouds, which are known as Nebulas. Our powerful telescopes have resolved many of these nebulas into star clusters so that at one time the question was raised as to whether they were not all composed entirely of stars. However, Sir William Huggins showed in 1864, with the newly invented spectroscope, that a true nebula is a cloudy mass of luminous gas and is not composed of stars.

Our modern telescopes now reveal about 300,000 nebulas, most of which are spiral in shape and are known as Spiral Nebulas. Since spiral nebulas are outside of our galaxy they will not be considered at this time. There are certain bright nebulas of irregular shape that are not very far from the earth and are well known to those who have studied the sky. Where do these bright nebulas get their light? They certainly are not hot like stars. This question may not be answered for some time but such nebulas are usually found near brilliant stars, so they may be shining by reflected starlight.

The most beautiful object of this type is the celebrated nebula in Orion which, at a distance of 900 light years, is visible to the naked eye through the middle star in the Sword of Orion. This Nebula is several million times as large as Neptune's orbit, being

ten light-years in diameter. When photographed through a large telescope it covers an area about four times the apparent size of the full moon.

Other well known bright diffuse nebulas are the Dumb Bell Nebula which gets its name from its shape, and the nebula about



Great Nebula in Orion.—Yerkes Observatory.

the Pleiades, which is thirty light-years in diameter and 220 light-years from the earth. In the constellation Cygnus we find the beautiful North American Nebula which very closely resembles an outline map of North America. In this same constellation appears another very irregular nebula which is many times as large as the celebrated nebula in Orion. These irregular diffuse nebulas, and almost all others of this type, lie in or near the Milky Way.

NEBULAS RESEMBLE CLOUDS IN APPEARANCE

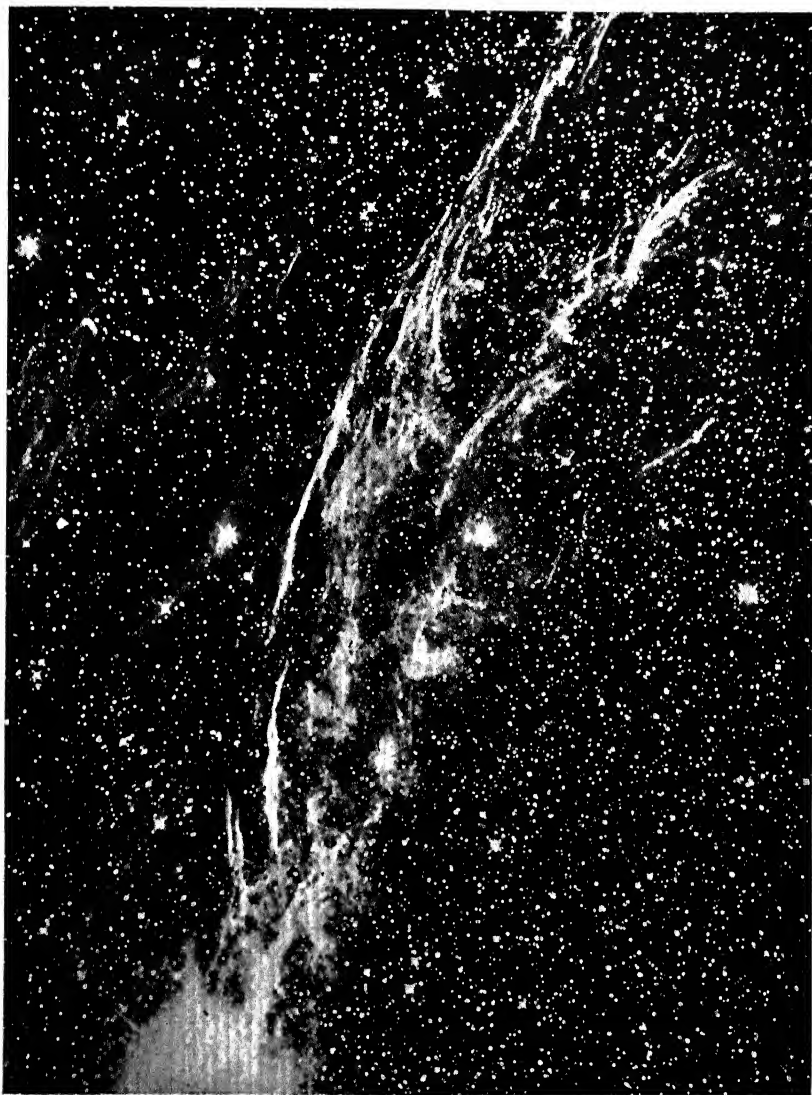
Many nebulas are circular or oval and have the appearance of a star with shells of matter around it. These are known as plane-

tary nebulas, not because they resemble planets but because they show faint disks through the telescope. The ring nebula in Lyra, which is said to have suggested the so-called Ring Nebula Theory of evolution of the solar system, is an example of this type, although rather an extreme case. The spectroscope shows that planetary nebulas are rotating, as might be expected from their shape.

Just as all stars in the sky are in motion so are nebulas moving in random directions. Some are approaching the earth while others are receding and the spectroscope reveals the fact that their radial velocities—their velocities in the line of sight—are comparable to those of the stars. There is also evidence of internal motion within several of the nebulas.

Nebulas resemble luminous clouds—but how different! Clouds are in the atmosphere of the earth, sometimes less than a mile away. Nebulas are immersed in the depths of space at such a distance that the light by which we see them tonight left the nebulas thousands of years ago. Clouds shine by reflecting the light of the sun while nebulas shine by their own light. Clouds change their shape and appearance and are blown about by the winds while nebulas always remain the same. If a photograph of a nebula be taken today and compared with a photograph taken many years ago it would be impossible to detect any change in the nebula. After a nebula has once been located it remains fixed in that part of the sky so that any person who knows its position may photograph it at any time. Of course nebulas actually do change, because change is the order of nature, but these changes are so slow that no human being can hope to live long enough to detect them. Clouds are much smaller than the earth while the smallest nebula is much larger than the sun.

While we are talking about nebulas it is interesting to note that these hazy patches of light seem to be composed of the same chemical elements that we find on the earth. In other words, animals, automobiles, radios, human brains, suns, moons, stars, and even nebulas are made of combinations of certain elements with which every chemist is familiar.



An interesting nebula in Cygnus.—Yerkes Observatory.

THERE ARE MANY DARK NEBULAS IN THE SKY

If you will look very closely at the Milky Way on any clear moonless night you will observe that this part of the heavens is sprinkled with very dim stars, which seem to be rather evenly distributed except that there are several "holes in the sky" in which

nothing is visible. Even after the invention of the telescope the astronomers for many years considered these dark spots in the Milky Way merely as openings through the stars that extended out into empty space. Our improved telescopes have recently revealed the true character of these dark spots. They are dark nebulas, bodies whose life history has been completed.

Photographs of certain sections of the sky reveal the presence of this dark nebulous material that is cutting off the light coming to us from luminous material farther away. Two well known examples of such dark clouds are the Coal Sack near the Southern Cross and the black spot south of Deneb in the Swan. In Barnard's catalogue there is a description of 349 of these dark nebulas, which are very numerous in the Milky Way. Perhaps our universe contains as many dark nebulas as bright nebulas.

The existence of dark nebulas raises an interesting question. Do we see all the stars? When we recall the fact that the sun when viewed from a distance of several hundred million miles would probably be very dim and faint, we naturally wonder whether there are not many other suns which refuse to reveal their presence even when we are armed with the most powerful telescopes that man has been able to construct. On the other hand, there are probably many dark stars in the sky, suns whose life history is ended and which are awaiting collisions with other stars before again becoming luminous bodies in the depths of space. Just as the number of people who have lived on the earth in past ages vastly exceeds the number of living ones, so we would expect the invisible dead suns to be much more numerous than those bright ones that are now shining upon us. In fact the sky seems to be more or less filled with dark bodies which actually cut out some of the light that is attempting to come to the earth from more distant suns. It is estimated that about one-fiftieth of the sky is covered with dark star-clouds that shut off the light from bright stars behind them.

THE MILKY WAY CONTAINS COUNTLESS MILLIONS OF STARS

Not only did Sir William Herschel, the great English practical astronomer, prove that our sun is merely a star which, like all

other stars, is moving through space, but he also determined the shape of our system of stars, which is usually called our "galaxy." It seems to have the shape of a watch or a biscuit. In other words



The Horse-head Nebula in Orion.—Mount Wilson Observatory.

our galaxy is round but it is flattened. When one looks in the direction of the edge of the watch—lengthwise through the galaxy—the stars seem to be much thicker. In fact in that direction the sky seems to be powdered with innumerable stars. This explains the Milky Way which has attracted the attention of

poets and philosophers throughout the ages. There are very few stars in the direction of the short diameter of the galaxy.

There are many myths and legends with reference to the Milky Way which is visible from all latitudes on the earth. We are all familiar with the story of Perseus and Andromeda and how the Milky Way was merely the dust that was raised by Perseus as he rode the Flying Horse through space to rescue Andromeda from the sea monster. Longfellow, in his *Hiawatha*, draws a beautiful picture of some of the Indian legends about the Milky Way. It is somewhat disappointing to have scientists tell us that the Milky Way is not the road to heaven traversed by the souls of the departed, but that this ring of star dust which apparently forms a complete circle around the sky does not exist at all—that it is merely an optical illusion due to the fact that our universe is very much longer in that direction, so that the stars in the Milky Way are not as close together as they seem.

With his little telescope Galileo, in 1610, discovered that the Milky Way was a mass of innumerable stars and larger instruments reveal multitudes of stars assembled in great clouds. Dr. Barnard at Yerkes made a special study of these star clouds, which are especially magnificent in the constellation Sagittarius, and his photographs were published after his death. On these photographs we find also 349 dark clouds which Dr. Barnard believed were not mere openings in the star clouds through which we look into the depths of space, but real dark bodies which cut off the light from anything that might be beyond.

OUR GALAXY HAS A DIAMETER OF 33,000 LIGHT-YEARS

We have known for some time that there are other worlds than ours which go round our sun and there are other suns than ours—we call them stars—which are moving with our sun perhaps around some central sun. But we now recognize the fact that the stars with which we are familiar form a single group—our galaxy—and we are asking ourselves whether there may not be other galaxies than ours lying in the depths of space.

According to the recent researches of R. J. Trumpler and

others the stars seem to be collected into groups, or clouds, and our galaxy—the star group to which our sun belongs—is a disk whose equatorial diameter is about 33,000 light-years and whose



The North American Nebula in Cygnus.—Yerkes Observatory.

thickness is about 3300 light-years. Our sun is now 1150 light-years from the center of our galaxy and thirty light-years north of its central plane. This galaxy contains all of the celestial objects—planets, planetoids, suns, moons, stars, comets, meteors,

open star clusters (mere details in our local star cloud), and nebulas—except the globular clusters and the spiral nebulas. Since our galaxy does not contain all of the objects that are visible in the sky we should not confuse it with our universe, a word which we are in the habit of using to denote the entire cosmos. Outside of our galaxy are the two Magellanic Clouds, the ninety-three globular clusters of stars and all of the spiral nebulas.

In order that we may appreciate the enormous dimensions of our galaxy we may say that ten trips around the earth are equal to a trip to the moon, 200 round trips to the moon would be equivalent to a trip to the sun, fifteen round trips to the sun would equal a trip to Neptune, 500 round trips to Neptune would equal a trip to the nearest star and 4000 round trips to this nearest star would not take us across the equatorial diameter of our galaxy.

Our galaxy—the Milky Way system—includes the sun and all the stars we can see but there are several celestial objects that lie entirely outside of our galaxy and we naturally wonder what they are. What lies beyond the Milky Way? Much time has recently been devoted to this problem and many suggestions have been made, some of which may probably turn out to be correct in the light of future researches.

INTERSTELLAR SPACE IS NOT EMPTY

The stars are so far apart that light—the swiftest messenger we know—requires many years to pass from one to the other, so we naturally wonder what lies in the open spaces between them. Are these immense intervals entirely empty and devoid of matter, or do they contain something which has as yet escaped the notice of man? The study of this question is very fascinating and research along this line has led to very puzzling results. However, the difficulties involved are certainly no greater than those which must be overcome by the physicist when he explores the atom of uranium and attempts to discover whether or not the space lying between the central nucleus and the ninety-two revolving electrons is empty, if the word “empty” can be applied to objects which we ordinarily think of as solid.

Soon after the invention of the telescope this remarkable instrument revealed the existence in interstellar space of Diffuse Nebulas—a name used to distinguish them from the Spiral Nebulas that lie entirely beyond our galaxy. Sir William Huggins in 1864 convinced the scientific world that Diffuse Nebulas are not composed of stars but are masses of luminous gas located in the immense intervals of space between the stars. Just how these interesting objects are related to the stars that make up our universe will perhaps be revealed at some later date.

Early in the twentieth century astronomers began to suspect the existence of invisible clouds of calcium gas in interstellar space, for only in this way were they able to account for the behavior of some of the lines in the spectra of certain double stars. What is the function of these calcium clouds and how are they related to the stars? Our scientists certainly have many interesting questions to which they can devote their attention in the years that are to come.

In 1930 the announcement was made that our galaxy seems to contain a large amount of interstellar dust that tends to redden some of the stars. This announcement precipitated much discussion and it is hardly necessary to say that the question has not yet been settled. At any rate it is obvious that interstellar space is by no means empty. There is no question about the existence of hundreds of Diffuse Nebulas in the “empty” space between the stars and future researches may prove the reality of the calcium clouds and the interstellar dust.

THE SPLENDOR OF OUR GALAXY IS BEYOND COMPREHENSION

Who can examine the heavens through the cold clear atmosphere of the winter season without being impressed by the beauty of the Milky Way that runs diagonally across the sky? We are told that every point of light in this luminous band represents a star that is sending its greetings to us across space from such an enormous distance that many of these light rays left these stars thousands and even hundreds of thousands of years ago. How many stars are in the sky? Surely no one would attempt to answer

this question. How could moral man ever hope to be able to count the millions of luminous points which, taken together, form the Milky Way? Surely the "Host of Heaven" cannot be numbered.

The human imagination cracks and our minds almost refuse to function when we realize that the stars in the Milky Way are really suns comparable with that brilliant orb from which we get our heat and light and to which we owe our very existence. It would be very difficult to spend much time exploring the depths of space without at the same time being deeply impressed by the greatness, the grandeur, the power and the infinite wisdom of a Creator who could bring this Galaxy into being and then keep it operating in an orderly manner.

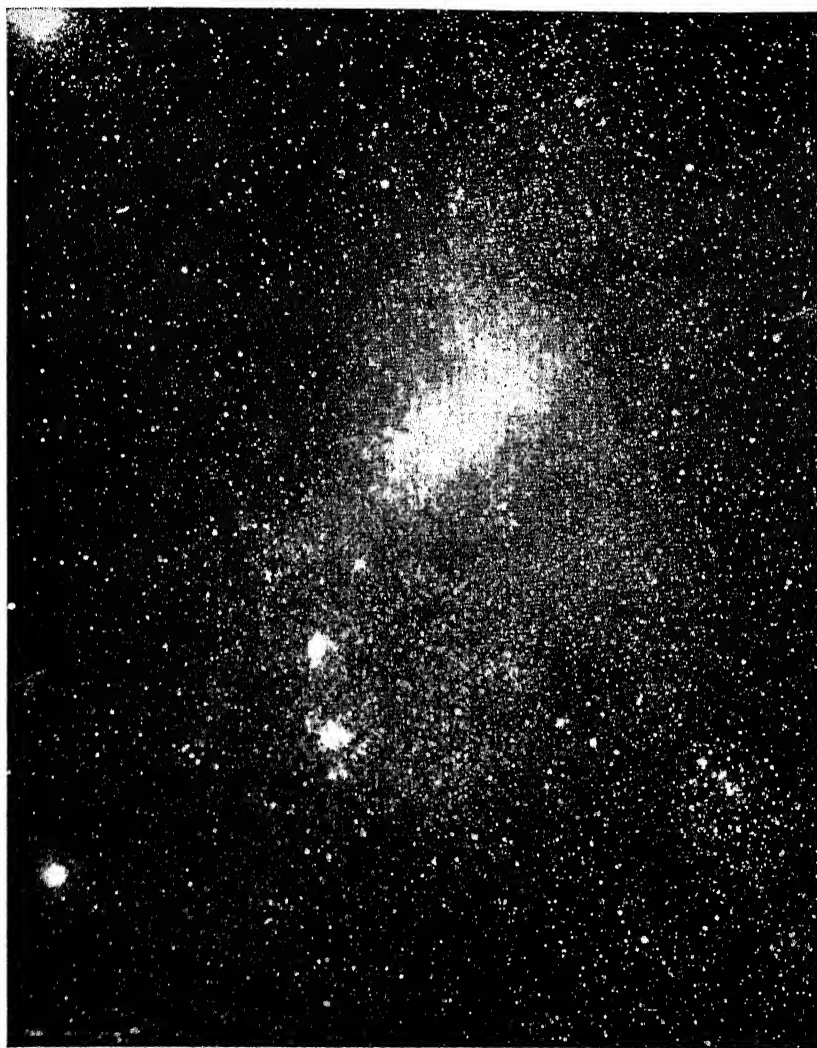
Under ordinary conditions the eye interprets the Milky Way as a band of slightly luminous, faintly visible matter, extending from the horizon, high overhead, and to the horizon again. If the atmosphere is clear the Galaxy affords a spectacle of transcendental beauty never to be forgotten. But when we endeavor to comprehend the indescribable splendor of our Galaxy within the Milky Way we find it necessary to coördinate into one system such varied classes of objects as billions of individual stars, some of which are accompanied by a retinue of planets; double and multiple stars forming smaller systems within the larger one; clusters of stars composed of hundreds or thousands of individual stars; and, finally, enormous quantities of tenuous gas, some of definite form and others confused and chaotic.

Even if our minds were capable of comprehending our own Galaxy we could not then remain at peace. The struggle goes on. Other "Galaxies" present themselves for consideration. Perhaps an enormous Galaxy is merely a unit in a larger system. Galaxies of galaxies. What could be more exhilarating to the mind or more stimulating to the imagination?

GLOBULAR CLUSTERS AND MAGELLANIC CLOUDS ARE BEYOND OUR GALAXY

What are those enormous globular clusters, each composed of millions of stars like our galaxy but of different shape? How are

they related to our galaxy? The fact that globular clusters are never visible near the Milky Way would lead one to believe that they are outside of our galaxy and that those which happen to



The Lesser Magellanic Cloud.—Arequipa Observatory.

lie in the direction of the Milky Way are hidden from our view by the dark nebulas which are so numerous in that part of the sky. Recent researches confirm our suspicions for we find that the nearest globular cluster, which is throwing its light waves toward us from behind the constellation Centaurus, is at a distance of

twenty thousand light-years. The ninety-three globular clusters are not so very far from our galaxy, as galactic distances go, for the farthest one is not more than two hundred thousand light-years away. Nevertheless, they are entirely outside of our galaxy which includes only those heavenly bodies that are encircled by the Milky Way.

We believe that the shape of a globular cluster is probably due to its age, and is the result of natural forces. Dr. F. R. Moulton suggests that the age of globular clusters must be counted in millions of millions of years. Perhaps these are other galaxies, composed of stars like our own galaxy, but many, many times as old.

In the southern sky are two isolated clouds of stars clearly visible to the unaided eye that are entirely outside of our galaxy, but are much nearer the sun than the average globular cluster. These star clouds are known as the Magellanic Clouds. From recent researches Dr. Shapley infers that the larger cloud, which is approximately circular, has a diameter of about 10,800 light-years—about one-third of the diameter of our galaxy—and is about 86,000 light-years away. The smaller cloud is only about 6000 light-years in diameter and is at a distance of 95,000 light-years from us. They are about 30,000 light-years apart. Both of these clouds are smaller than our own galaxy and seem to be of an entirely different shape. They are sufficiently near the earth to be resolved by our telescopes into stars like our own stars and star clusters and both bright and dark nebulas like those of our own galaxy. Each of these clouds is receding from us at the rate of more than one hundred miles per second.

OUR GALAXY BELONGS TO A SUPER-GALAXY

Our galaxy, together with the ninety-three globular clusters and the two Magellanic Clouds, forms a sort of super-galaxy in space. According to recent researches of Dr. Shapley the least and greatest diameters of this super-galaxy are about 20,000 and 200,000 light-years and our solar system is about 52,000 light-years from the center. In other words, the light which now reaches us from the center of our super-galaxy left that point at a

time when our civilization was entirely different from what we have on the earth today.

The center, around which our sun and all of the other stars in our super-galaxy appear to revolve, is in the direction of the constellation Sagittarius (the Archer), but many thousands of times as far away. Dr. Shapley has announced that there is an enormous mass of stars concentrated near this point, their number being estimated to be at least 100 million.

Not only are we living in the suburbs of our super-galaxy but our suburb is moving, for every part of our super-galaxy seems to be revolving about this mysterious center. Since our super-galaxy is made up of separate units the part nearer the center must revolve faster. At our distance from the center it takes us about 300 million years to make one complete trip.

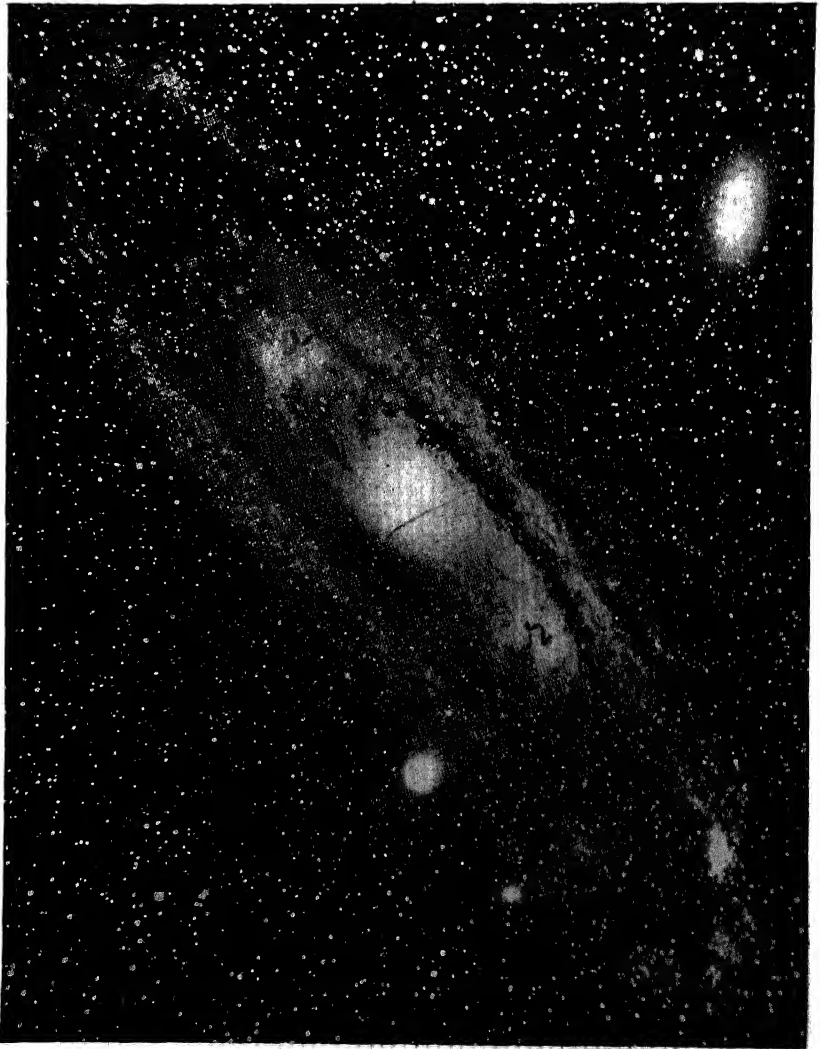
What lies beyond our own super-galaxy? This is a question that can be answered only after years of research and discovery. However, at the present time it is possible to point out many objects in the sky that are known to be outside of our own super-galaxy because they do not belong to that mass of suns, moons, stars, planets, comets, star-clusters, nebulae, etc., which are whirling about that mysterious center in the direction of Sagittarius.

The thousands of nebulae in the sky can be divided roughly into three groups—the planetary nebulae, the irregular nebulae and the spiral nebulae. As we increase the power of our telescopes more and more planetary and irregular nebulae are finally proved to be clouds of glowing gases inside of our galaxy. However, from photographs made soon after the completion of the 100-inch telescope of the Mt. Wilson Observatory, we are convinced that the spiral nebulae are made up of stars and there is no question but these “pin-wheels of space” are outside of our super-galaxy.

SPIRAL NEBULAE ARE GALAXIES SIMILAR TO OUR OWN

There is no question but that every spiral nebula is composed of stars similar to those in our own galaxy, and recent researches have shown that these stars are all revolving around some central

point inside the nebula. In fact it is not hard to believe that our own galaxy when looked at from some outside position far away in the depths of space would have the general appearance of a spiral nebula. We know that all the stars in our galaxy are in motion and, to an observer in some other galaxy, they would probably appear to be moving around some central point exactly as the stars in the spiral nebulas are doing. All spiral nebulas



The Great Nebula in Andromeda.—Yerkes Observatory.

resemble in a general way snail shells with arms radiating in all directions. They are of course flattened like our own galaxy and an observer living in one of these galaxies would probably have in his sky a Milky Way somewhat similar to ours and for the same reason.

Every spiral nebula is another galaxy that is far beyond the Milky Way. Because of the dark nebulous material in and near the Milky Way the spirals in that part of the sky are much dimmer than those farther from the Milky Way. This explains why spiral nebulas are never found in the actual direction of the Milky Way. All of the light from the nebulas in that direction is apparently being cut off by the dark star-clouds in space.

The most famous one of the spirals is known as the Great Nebula in Andromeda because it is in the direction of—though far beyond—the constellation Andromeda. This neighboring galaxy has an apparent diameter about equal to that of the full moon and on a clear, moonless night most people can see it very plainly with the naked eye. This is the most remote object visible without optical aid.

The actual diameter of the Great Nebula in Andromeda is about 42,000 light-years so that this exterior galaxy is not much larger than our own Milky Way system of stars. Its distance from us is about 900,000 light-years which puts it far beyond what we have called our super-galaxy. Near the end of the handle of the Big Dipper is another beautiful spiral, known as the "Whirlpool Nebula," which is rich in detail when photographed through our modern telescopes. There are thousands of others.

THE UNIVERSE CONTAINS THOUSANDS OF GALAXIES

It now appears that not only are there other worlds than ours, other suns than ours, but there are also other galaxies than ours. The 93 globular clusters and the two Magellanic Clouds, which are visible only in southern latitudes and have the appearance of having been broken off from the Milky Way, are the nearest galaxies to the one in which we live. Then follows an irregular nebula beyond Sagittarius which is at a distance of about 700,000

light-years. This galaxy is much smaller than our Milky Way system. In the direction of the constellation Triangulum there is a spiral nebula at a distance of 850,000 light-years. This is the nearest of the external spirals and next comes the Great Nebula in Andromeda whose light reaches us only after 900,000 years. As far as we have been able to determine these ninety-eight exterior galaxies are the only ones within one million light-years of our sun.

Although the distance to these exterior galaxies is so great that it causes our imagination to "crack," two globular clusters and four of the other five galaxies—all except the one beyond Sagittarius—are visible to the naked eye. If our own galaxy should suddenly be erased from the universe the entire sky would become blank except for these six objects.

The first spiral nebula was discovered by the Earl of Rosse, an Irish amateur astronomer, in 1845 and the improvement of the telescope has increased this number until it now seems that there are hundreds of thousands of these galaxies in the sky. These spiral nebulas contain star clusters, bright nebulas, dark nebulas and every kind of celestial object that we find in our own galaxy. All of these "pin-wheels of space" have a motion of rotation similar to the movement of the parts of our own Milky Way system.

Each of the hundreds of thousands of galaxies that have been discovered seems to be going on its way independent of the others. Both of the Magellanic Clouds are receding from us more than 100 miles a second, but the Great Spiral in Andromeda is approaching our galaxy at the rate of 185 miles a second. Where are these galaxies going and why? Such questions must remain unanswered for the present, but we must conclude that space is infinite and that many more galaxies are moving about in the distance, to be picked up later by more powerful telescopes.

MUCH OF THE UNIVERSE IS INVISIBLE

If your imagination staggers when you attempt to contemplate the immensity of space in which thousands of galaxies are racing

about, many of which are larger than ours but so far away that their existence is revealed only by the most powerful optical aid, you should recall that there are just as many wonderful parts of



A spiral nebula in Andromeda seen edgewise.—Yerkes Observatory.

space that are beyond our senses because they are too small. It is no more difficult to imagine a cluster of stars so large that light requires 200 years to move across it than to picture bacteria so small that 100,000 of them could sit side by side on a telephone

wire not more than an inch long. Yet we must recognize the existence of these invisible objects for, in spite of their minute size, the human race must constantly wage war against them. It seems that one by one the wise sayings of our forefathers must be discarded. "Seeing is believing"—surely this statement is not true. We see many things which we are not able to believe and there are many, many things that we cannot see but whose existence we cannot help but feel.

There is much light that we are unable to see, many sounds that we cannot hear, and movements that we cannot feel. At one time the atom was considered to be the smallest possible particle of matter and when a chemical element was separated into atoms the task of the chemist was complete. We now know that every atom is made up of a central nucleus with a number of electrons revolving around it. Think of the motion that is taking place in this sheet of paper upon which these words are printed.

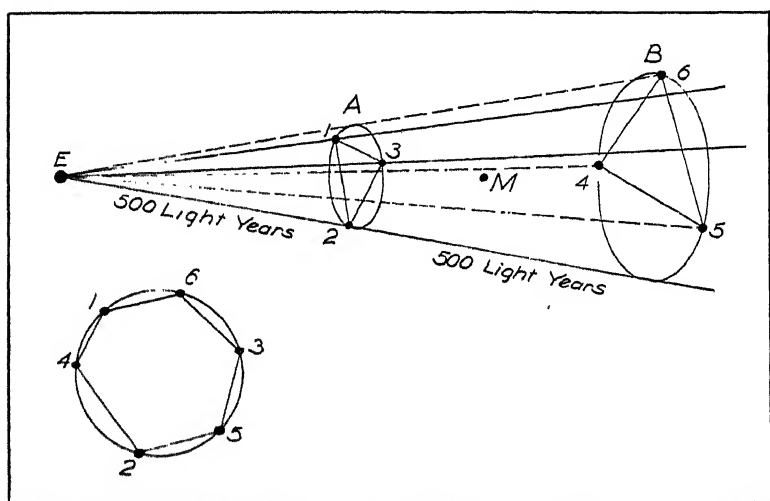
A hydrogen atom is composed of a nucleus of hydrogen and one revolving electron; a helium atom is composed of a nucleus of helium and two revolving electrons, and so on down the scale to an atom of uranium (the heaviest known element) which is composed of a nucleus of uranium and 92 revolving electrons. In fact our modern scientists, after making a study of the number of electrons in atoms of different chemical elements, have actually found atoms whose electrons correspond to all of the numbers 1, 2, 3,—up to 92, inclusive. We are accustomed to thinking of gigantic solar systems composed of central suns and revolving planets. Here are microscopic solar systems of 92 different varieties.

THINGS ARE NOW WHAT THEY SEEM

As we look out through the universe and study the sky maps in order to identify certain stars we should remember that there is a fundamental difference between maps of the sky showing the stars and constellations and maps of parts of the surface of the earth. Unless we wish to take account of the slight difference in altitude of different parts of the earth—our globe is as smooth as a billiard ball—we usually think of terrestrial maps as having only two dimensions, length and breadth. Maps of the sky must of

necessity be considered as three dimensional—length, breadth and depth. What we actually see is the projection of the stars into space so that they all seem to be at the same distance from the earth, but, as a matter of fact, these distances vary greatly.

A simple example will show how this difference in distance affects our maps of the sky and makes us combine certain stars into constellations when, as a matter of fact, these stars are merely optically connected and are not anywhere near each other in space. Let us assume that there are three stars—1, 2 and 3—at A in space and three other stars—4, 5 and 6—in a remote part of space at B, and arranged as shown in the figure. Let us now



A group of stars might resemble a hexagon when, as a matter of fact, they really compose two triangles in remotely separated parts of space.

suppose that we look at these two triangular sets of stars from our position at E on the earth. Do we see two triangular constellations? Certainly not. We see these six stars in the form of a hexagon, as indicated in the figure, and we would probably call this hypothetical constellation The Hexagon, because of its shape although this hexagonal star-group does not exist at all.

For convenience stars are grouped to form constellations not because of any physical connection between them, but merely for the reason that as viewed from the earth they lie in about the same direction. Observers in other parts of space would see an entirely different set of constellations from those visible to us.

The stars that form our Big Dipper, our Northern Crown and our Scorpion would not resemble a dipper, a crown, or a scorpion when viewed from other parts of the universe. In fact our hypothetical Hexagon would appear as two Triangles located in opposite sections of the sky if the earth happened to be situated at M in the space between them.

STAR MAPS HAVE FOUR DIMENSIONS

When we consult a map of the United States we note that Chicago, Atlanta and Denver are fixed on the surface of the earth and form a triangle which will remain unchanged in size and shape through the ages. Let us now look on our star map at the group of seven stars in the north arranged roughly in the form of a dipper. Throughout the life of a single human being this constellation will remain unchanged in appearance, but we know that every star in the sky is in motion and that five of the stars of the Dipper are moving in one direction and that the other two—the end stars—are moving in another direction, so that after a short time—astronomically speaking—the relative position of these stars will have been changed to such an extent that this group can no longer be called The Dipper.

We usually think of maps of the sky as having three dimensions—length, breadth and depth—but to be strictly exact we should add a fourth dimension—time. The map of the United States shows our terrestrial triangle—Chicago, Atlanta and Denver—as it is today, but maps of the sky show the different stars, not in the positions they occupy today, but as they were hundreds, thousands and even millions of years ago. We see our star-triangle at A as it appeared about fifty years before Columbus discovered America and the triangle B presents the appearance it had about a century before William of Normandy won the Battle of Hastings and ascended the throne of England. What could be more fascinating than to realize, as we look at our hypothetical Hexagon, that not only is this constellation a composite picture of two different star-groups, but also that we have here combined into a single group-picture two changing elements that are 500 years apart?

The element of time rarely enters into a single terrestrial map or picture for surely we would never think of printing a group-picture of a man and his family which showed the father as he was fifty years ago, the mother as she appeared twenty-five years ago, and the children as they are today. Yet, because light requires an interval of time for transmission from one part of space to another, we must be satisfied with this kind of a picture of constellations and star-groups.

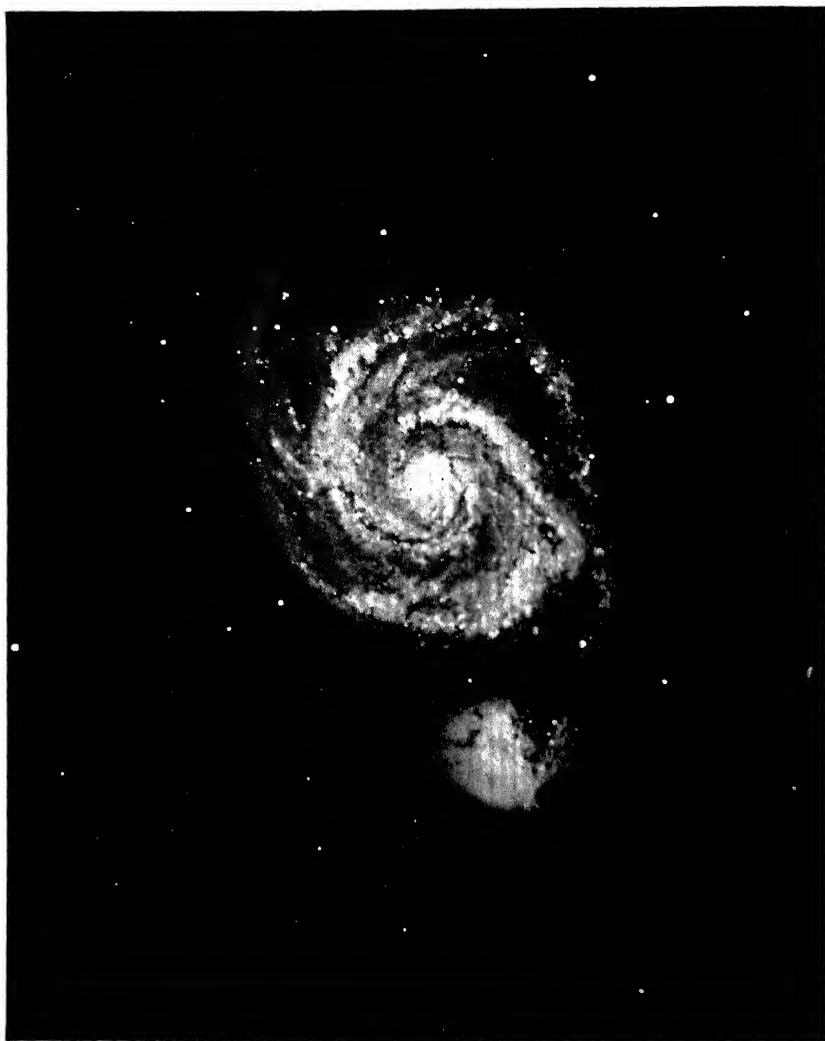
THE TELESCOPE BRINGS THE PAST TO THE PRESENT

The astronomer is absolutely dependent upon his sense of sight and all his knowledge of the sun, moon, stars and other objects in the sky is obtained by studying the light that comes to him from these heavenly bodies. No matter whether he calls to his assistance the telescope, the spectroscope or some other kind of "scope"—a Greek word meaning "to see"—the extent of his knowledge of the heavens will depend solely upon his ability to correctly interpret the messages the different celestial bodies are continually sending him by means of rays of light—the most universal of all languages. When Roemer, in 1675, announced that light did not travel instantaneously, but that a certain amount of time was required for it to move from one part of space to another, astronomers immediately realized that they were studying the ancient history of the stars and not the current events in the universe.

Rays of light report earthly affairs in a fraction of a second and bring information from the planets in a few moments or hours, but the story they tell about the stars is hundreds and thousands of years old and the information they convey about other galaxies deals with conditions as they were millions of years ago. Our modern telescopes are strong enough to reveal galaxies at a distance of 250 million light-years.

As we look through our gigantic telescopes into space beyond our galaxy we at once realize that the telescope penetrates into time as well as distance. It brings the past to the present. From these far away stars and nebulae the light and energy of past

ages are brought before our very eyes. Their past is brought to the present and what they are like now will not be known for thousands and millions of years.



This spiral nebula is separated from us by more than a million light-years.—Yerkes Observatory.

It has frequently been said that time and distance are merely relative after all. We are beginning to realize this fact because we can now make a trip from New York to San Francisco using modern methods of transportation, in just about the time re-

quired for a trip of 100 miles several centuries ago. We are, therefore, somewhat prepared for the extension of the scale of objects from electrons to atoms, from atoms to molecules, from molecules to worlds, from worlds to suns, from suns to galaxies, from galaxies to super-galaxies, from super-galaxies to universes, from universes to—what?

CHAPTER VIII

An Astronomer Looks at His Universe

THE CHARTER OF SCIENCE IS FOUND IN GENESIS

Who can study the science of astronomy and contemplate the star-lit heavens with a knowledge of the dimensions of the celestial bodies, their movements and their enormous distances, without bowing his head in reverence to the power that brought this universe into being and safely guides its individual members? From earliest times the most religious people have been the astronomers—those who had some idea as to their relation to the universe. What is a man's religion? Does it not depend upon his outlook on the universe?

Astronomy and religion cannot be separated. No minister of the Gospel can explain some parts of the Bible without first studying his universe. The Bible is not a textbook on science and it was not written for that purpose. However, it contains many scientific statements that are absolutely correct. In fact if the author of the Book of Job was not an expert astronomer of his day, he at least knew much more about the subject than the average person gives him credit for knowing. Buried deep within the pages of this Book are many hidden astronomical truths that are evident only to those who have made a special study of the universe.

The Charter of modern science is expressed in the first verse of Genesis, "In the beginning God created the Heavens and the Earth." In our study of arithmetic we found it necessary to memorize certain multiplication tables which we were told were necessary before much progress could be made in this field. We have learned from experience that the facts expressed in these tables are true in any language and on any part of the globe.

When we come to make application of the multiplication tables to the complex problems of modern life we sometimes arrive at contradictory results, not because our tables are in error, but for the simple reason that we have made improper deductions from them.

In a similar manner we may work out a scientific theory which turns out to be quite erroneous although based upon correct premises. No truer statement can be found in any scientific textbook than the one expressed in the Charter of Science and no real scientist would attempt to go behind that statement. If any errors creep into the development of the science of astronomy they are due to our mistakes and cannot be charged against the fundamental hypothesis upon which we base our deductions.

SCIENCE DOES NOT CONFLICT WITH RELIGION

Where is the much heralded conflict between science and religion that is talked about so fluently by those who know little about either science or religion? Some people would have us believe that scientists and the religious sects of the country are constantly at each other's throats and that the result of this conflict will determine whether science or religion shall survive as a part of our civilization. As a matter of fact all thinking people who understand the fundamentals of both science and religion realize that there is no conflict whatsoever between these two forces which are so powerful and so important in the development of the human race.

Science and religion work in perfect harmony and why should they not continue to do so? Their aims and objects are the same—to create a future race of men that will be healthier, happier, saner, more virtuous and more intelligent than the men of today. Out of the ninety-two chemical elements that are to be found on the earth, in the water, and in the air, the scientist builds foods and life-saving medicines, he generates electricity—the newly discovered servant of man—and he arranges methods of long distance communication and rapid transit, but he makes no attempt to build a chemist, a physicist, or an electrician. The question as to how and why a number of these chemical elements got to-

gether to form a human being that is able to think and to study about other combinations of the same elements cannot be answered by the scientist without an excursion into the realm of theory.

Man's ideas about religion have gradually developed down through the ages and have been interpreted by so many different theologians that we now have hundreds of religious sects and scores of man-made creeds, no two of which are in perfect agreement and some of which are absolutely contradictory. It is also true that many theories about science have been proposed and developed which do not agree with each other and some of which are of such a nature that if one theory is true all of the others are false. But theology is not religion any more than the theory of relativity is science. If our theologians are unable to agree and our theories about science contradict each other, is it any wonder that a certain creed may be in conflict with a certain scientific theory?

SCIENCE WILL HELP—NOT INJURE—RELIGION

Will science destroy religion? Not unless it first destroys the universe in which we live. The scientist is a thinking man and every thinking man is a religious man, whether he admits it or not. He cannot live in this universe with its mysteries, its harmonies, and its inspiring beauty without wondering what lies beyond and what is the purpose of it all. The scientist lives in an atmosphere of freedom—freedom of thought and freedom of imagination. He is bound by no dogma or creed. He devotes his life to the study of his universe, not only those parts that are visible but also those that are beyond his senses—so far away that they cannot be reached by his gigantic telescopes or so small that his powerful microscopes do not reveal them. The gigantic solar system—nine planets revolving about a central sun—appeals to him and so does the similar machine which he finds inside of the atom. The scientist spends his life in an effort to find out more about his universe and to bring himself into the proper relation with its governing powers. If this is not religion, then what is it?

Will religion destroy science? Not unless it first destroys man's imagination and his curiosity about his universe. Man's religion—his outlook upon his universe—is obtained for the most part from science and it has been expressed differently in different periods of our history. Primitive man lived in constant dread of the forces of nature—plague, pestilence and famine—and science, as yet unborn, could not help him combat them. He tried to appease them with sacrifices and offerings and naturally developed a religion of fear. One by one the forces of nature have been conquered by science and man has been given a new outlook upon his universe, so that the old religion of fear and vengeance has gradually disappeared. The theologian adopts the scientific ideas with reference to his expanding universe and gets a bigger, a broader, and a grander notion of his Creator than he ever had before.

Theologians may ridicule one or more of the many theories of science and scientists may be unwilling to subscribe to one or more of the many systems of theology, but both the theologian and the scientist agree that the more we turn the searchlight of science on the Bible the more real scientific truths we discover in it.

GENESIS GIVES A TRUE ACCOUNT OF CREATION

In the Book of Genesis we find two stories about the creation of the earth which were probably collected from different sources. In the first chapter the author uses the seven-day week, with which most early peoples were familiar, as a frame upon which to hang his story and describes the events in a very few words but in exact agreement with modern scientific thought. Of course this story covers the history of millions of years but what is a million years in comparison with the life of a universe? Since man has been on the earth several hundred thousand years the date of the last stage of creation, like that of the first, belongs to the dim distant past, and those who make the statement that creation was completed on October 21, 4004 B. C. at nine o'clock in the morning are merely making themselves ridiculous.

Not only does science recognize six different stages in the

creation of the earth, culminating in the advent of animals and man during the sixth stage, but the order in which the scientists believe the different parts of the universe were created is exactly the same as specified in Genesis. Science teaches that in the beginning the material out of which the earth was to be constructed was scattered about in hopeless confusion throughout the original nebula and Genesis says, "The earth was without form and void."

Science claims that the molecules were set in motion throughout the nebula and thus the vibration of light originated and Genesis says, "Let there be light and there was light." During the second stage the earth settled down into a globular shape and the atmosphere was formed. Genesis describes the creation of the firmament (atmosphere) on the second day. Science claims that while the atmosphere was still dense the oceans began to settle in the low places and Genesis describes the formation of land and sea and vegetable life on the third day. The atmosphere then became thinner so that the sun, moon and stars became visible for the first time. Genesis describes the creation of the sun and the moon on the fourth day. Science claims that the animal kingdom is younger than the vegetable kingdom and Genesis describes the creation of beasts and fowls on the fifth day. Science teaches that the highest type of animal life is man. Genesis confirms this and states that man was created on the sixth day.

THE BIBLICAL EARTH NEEDED NO SUPPORTS

What holds the earth up? This question is answered in the seventh verse of the twenty-sixth chapter of Job in words that cannot be misunderstood, "He hangeth the earth upon nothing." No modern scientist could make a clearer or a more accurate statement as to the manner in which the earth is supported. We find in the Bible several references to the "Pillars of the Earth" such as I Samuel (2:8) but these are merely poetical figures of speech such as are to be found in the literature of the twentieth century. It is said that Luther, Calvin and Wesley erroneously taught that the earth was prevented from falling by some kind

of supports, but this is their error and not an error in the Old Testament.

What a pity that those early leaders who insisted upon a literal interpretation of the Scriptures overlooked this statement, which means exactly what it says. A literal interpretation of this verse in the Book of Job would have eliminated much discussion and saved much time which might have been devoted to something more worth while.

Some religious fanatics today insist that we are living on a flat earth, claiming to base this belief upon the Bible. There is no statement in the Bible to this effect. The fact that the visible horizon is a circle is just as true today as it was in the time of Job who said, "God fixed the circle as a limit to the waters," but this does not mean that the earth is flat.

The statement in Jeremiah (49:36) about the "Four winds from the four quarters of heaven" is merely a reference to the four points of the compass. Similar expressions are frequently used today. Yet some of the early theologians argued from this text that the earth was flat and had four sides like the top of a table. Again, the error was theirs and not in the Bible.

The Jews, like all other early peoples, believed that their own country was located at the center of the earth for in Ezekiel (5:5) we find, "This is Jerusalem: I have set her in the midst of the nations." There is nothing wrong with this statement since, no matter where an observer may be living on the earth, a line that points straight down will point to the center of the earth and he is always "on the top of the world."

DISTANCE TO SKY CANNOT BE MEASURED

We need not be surprised that the Biblical writers had rather vague ideas about the size of the earth for, as Job (38:5) says, no one at that time had "stretched the line upon" the earth to measure it. As a matter of fact, this was not accomplished for several thousand years.

The Biblical firmament is the atmosphere which completely surrounds the earth and in which the clouds are suspended, so that the statement that the firmament "divided the waters which

were under the firmament from the waters which were above the firmament" is scientifically correct. In Job (26:8) and (36:27-28) and also in Genesis (1:7) the meaning of the word firmament is very clear. Here it is stated that its main duty is to support the upper waters—the clouds. In the Old Testament we find several references to the firmament as a mirror, as in Job (37:18). This is of course just another example of poetic license. It is obvious that the early Hebrews understood the meaning of the rainbow, Genesis (9:13), which announces the end of the rain-storm just as faithfully in the twentieth century as it did in Biblical times.

When the literature of all ages contains statements such as "the windows of heaven were opened"—an excellent way to stress the violence of a rain-storm—how can we find fault with Genesis (7:11) and the other parts of the Old Testament where similar poetical references are made to the windows of heaven? Unfortunately these statements were interpreted literally by some of the early Fathers of the Church, who even taught that the firmament was solid and that it held up the water that was necessary to cool the axis of the earth. This was their error and not an error in the Bible.

Beyond the firmament is the sky which, as Jeremiah (31:37) plainly states, is at such a great distance from the earth that it cannot be measured. Science confirms this when it reveals the fact that a radio message, traveling at a speed that would take it around the earth seven times in one second, would require four years and four months to reach the nearest star. Recent researches have extended our universe until we are now familiar with spiral nebulas—one of which was visible to Jeremiah—at such enormous distances that their light rays require almost a million years to reach the earth.

PRIMITIVE MAN WORSHIPPED THE SUN

Primitive man lived out of doors under the open canopy of the sky. The sun, moon and stars not only regulated his calendar but they also furnished him a religion which at one time seems to have been world-wide. He watched the sun daily perform

miracles in plants, trees and animals and soon came to realize that he owed his very existence to that magnificent Day Star. Is it any wonder that he looked upon the sun as his principal god, who must be appeased with sacrifices and burnt offerings if man wished to attain any degree of happiness and comfort? Who can read those inspiring legends about the sun gods—Ra, Osiris, Mithra, Baal, Brahma, Hercules, Helios, Apollo and Perseus—which primitive man first wrote indelibly in the sky and then handed down by word of mouth, without a feeling of respect for the religion of early peoples?

To the astronomer the sun is "monarch of all he surveys." There is but one law in his realm—the Law of Gravitation. Scientific research has revealed the fact that the sun is more than a million times as large as the earth and that there is nothing in our corner of the universe that can compare with it in size, but the writers of the Old Testament seem to have discovered this fact for they looked upon the sun as the most magnificent work of the Creator, Psalms (19:5). The early Hebrews were not sun-worshippers but we learn from II Kings (17:16) that the Israelites found the worship of Baal existing in Palestine, and from Jeremiah (7:18) that certain peoples worshipped the moon—the Queen of Heaven.

As a result of sun-worship early peoples daily watched the eastern horizon to catch a glimpse of the rising sun so that their most important direction was toward the east. Consequently early maps were drawn with east, rather than north, at the top. The Bible tells us that the Garden of Eden was in the east and that the Land of Nod—the abode of Cain—was east of Eden.

We now use the sun and the moon principally for determining the seasons and the Biblical writers plainly stated that this was the object for which they were created, Psalms (104:19). Modern astronomers thoroughly understand the phases of the moon and can predict them with great accuracy, but the early Hebrews could also predict them for in I Samuel (20:5) David said, "Behold, tomorrow is the new moon."

BIBLICAL WRITERS DID NOT UNDERSTAND ECLIPSES

The writers of both the Old and the New Testament, like all the other people of their day, looked upon the sun, moon and stars as the "regular" parts of the universe which had been created for the benefit and enjoyment of man. Early peoples became accustomed to their daily movements and regulated their lives by them. They believed that the main purpose of the sun and moon was to mark the seasons and to measure time so that it was absolutely necessary that they move regularly and without interruption. In what way could the primitive poets better convince their readers of the power and strength of their heroes than to have them stop or turn back one of these heavenly bodies, II Kings (20:11)?

On rare occasions when the light of the sun would go out, or the moon would change to a dull copper color (when eclipsed), or a star with a long tail (comet) would appear, or a meteor would flash across the sky, primitive man was convinced that here was a "sign" that something terrible was about to happen. Jeremiah (10:2) probably knew better for he said, "Do not be dismayed at the signs of heaven."

An eclipse of the sun occurred at noon in Palestine in 763 B.C., which was probably witnessed by both Joel and Amos. At any rate Amos (8:9) writes, "I will cause the sun to go down at noon, and I will darken the earth in the clear day," and Joel (2:31) says, "The sun shall be turned into darkness, and the moon into blood." Again in Job (5:14), "They meet with darkness in the daytime, and grope at noonday as in the night." Isaiah (13:10) says, "The sun shall be darkened in his going forth, and the moon shall not cause its light to shine," and again in (16:3), "Make thy shade as the night in the midst of the noonday." Joel (2:30) probably had in mind a comet when he spoke of "pillars of smoke."

Matthew (24:29) refers to eclipses of the sun and moon and also to meteors, "The sun shall be darkened and the moon shall not give her light, and the stars shall fall from heaven." A similar reference is found in Revelation (6:12-13), "And the sun became black as sackcloth of hair, and the whole moon be-

came as blood; and the stars of the heaven fell upon the earth," and again (8:10), "There fell from heaven a great star, burning as a torch."

THE STARS CANNOT BE NUMBERED

All early peoples were on more or less intimate terms with the planets Mercury, Venus, Mars, Jupiter and Saturn so that we naturally expect to find in the Bible references to these wandering stars. The planet Venus is sometimes Morning Star and sometimes Evening Star and on certain occasions our twin world is so bright that it may be seen in the day time. Isaiah (14:12) must have had in mind this planet when he spoke of "the Day-Star, son of the morning." As they wander through the Zodiac the planets sometimes appear rather close together in the sky. Job (38:7) seems to have referred to such a conjunction when he said, "The morning stars sang together."

How many stars are in the sky? In the entire heavens there are less than 5000 visible to the naked eye, and less than 3000 of these can be seen from Palestine, but Job (26:14) realized that some parts of the universe were hidden from view, "Lo, these are but the outskirts of His ways." Although Jeremiah could easily have counted all the visible stars, he said (33:22), "The Host of Heaven cannot be numbered." Modern astronomers agree with Job and Jeremiah for every time we increase the power of our telescopes we bring more stars into view and the sensitive plate now reveals many billions.

In the Old Testament "The Host of Heaven" seems to have been used with different meanings by various writers. In Genesis (2:1), in Jeremiah (33:22) and in certain other places the reference is probably to the entire equipment of heaven—the sun, the moon and the stars. The references in II Kings (17:16) where they "worshipped all the Host of Heaven, and served Baal" and in Deuteronomy (4:19) seem to be to the stars. At one time the worship of the heavenly bodies was very common, but we learn from II Kings (23:12) that it was later abolished by Josiah. When Nehemiah (9:6) said, "The Host of Heaven worshippeth Thee," he seems to have been referring to a heavenly council that was supposed to execute the will of God.

Who can go out under the canopy of heaven and look at the thousands of stars—now known to be suns—as they throw their light rays toward us over millions of miles of empty space without a feeling of deep reverence for the power and wisdom of the Divine Creator? Surely Job (26:14) spoke the truth when he asked, “But the thunder of his power, who can understand?”

THE HEAVENS DECLARE THE GLORY OF GOD

We would naturally expect to find in the Old Testament references to the oldest and best known star-groups. Job (9:9) was talking about stars with which everyone was acquainted when he referred to Him “that makest the Bear, Orion and the Pleiades.” Amos (5:8) also said, “Seek Him that maketh the Pleiades and Orion.” These groups of stars are just as well known today as they were in Biblical times. The writers of the Old Testament must have been familiar with the Signs of the Zodiac for they seem to have been used as insignia by the twelve tribes of Israel. The Zodiac was very closely related to the astrology of early times but we find very little reference to astrology in the Bible. The Jews were probably the only nation to escape domination by the astrologers.

Everyone now knows that stars differ both in color and brightness. Vega is bluish-white, Arcturus is red, and Capella is yellow. Some stars are of the first magnitude, others of the second magnitude, etc., and modern telescopes reveal still other differences between individual stars. This fact was well known to Saint Paul for in I Cor. (15:41) he wrote, “One star differeth from another star in glory.”

In Job (38:31-32) Jehovah asks Job, “Canst Thou bind the cluster of the Pleiades or loose the bands of Orion? Canst Thou lead forth the signs of the Zodiac in their season? Or canst Thou guide Arcturus and his sons?” Of course the Signs of the Zodiac were well known at that time, but the other two questions have a hidden meaning which became evident when science revealed the fact that all stars are in motion in random directions at different speeds and that Arcturus is the fastest moving bright star.

Because of this motion of individual stars all constellations gradually change their shape, except the Pleiades and Orion. The stars in these two groups seem to be tied together by some invisible force so that these constellations drift along unchanged. Modern science has made it evident that Jehovah was calling the attention of Job to the fact that He could guide the fastest moving bright star and that He had tied up the Pleiades and Orion so that their appearance would remain unchanged forever. The more astronomical discoveries we make the more we agree with the Psalmist of old who sang—"The heavens declare the glory of God and the firmament sheweth His handiwork."

THE WORLD WILL END WHEN LIFE DISAPPEARS

When will the world come to an end? Astronomers have been asked this question all down through the ages. Of course no real scientist would attempt to give a definite answer, but still it seems natural to ask him because he is supposed to know something about the furniture and framework of the universe, which will surely crumble on the day the world comes to an end.

The meaning of this question depends entirely upon man's outlook upon his universe. In the early history of the human race, when man was sure that the earth was the center of everything and the object of creation, the end of the world meant the end of the entire universe. But man's universe has continued to expand until he is now forced to admit that he is living on a very small planet that is revolving around a rather small star. He realizes that the complete destruction of the sun and all of the nine planets which it controls would have no effect whatever on the other suns (stars) which seem to be scattered throughout the length and breadth of space.

In view of our present information about our universe the question as to when the world will come to an end merely means when will all life on the earth disappear, for as far as the human race is concerned the entire world will then have come to an end. Of course from the point of view of any individual his world comes to an end when he passes out of existence.

The early Christians were convinced that the end of the

world was not very far away, for the Acts of the Apostles apparently announced the arrival of this event before the present generation had passed away. About the middle of the tenth century an announcement was made that the world would come to an end in the year 992 A.D. This announcement came from such an authoritative source that it could not be denied and everyone agreed that the year 992 A.D. would end it all. So firmly was this idea fixed in the minds of the people that all Royal proclamations during the latter part of the tenth century began with the words, "Whereas the end of the world is approaching." Of course nothing happened in 992 and the people then settled down to enjoy a few more years of life and again await the end of the world.

CONJUNCTION OF PLANETS FORETOLD END OF WORLD

As the planets make their regular trips through the constellations of the Zodiac it sometimes happens that several of them are in the same part of the sky at the same time. Early in the year 1186 the astrologers announced that a conjunction of all the planets would occur in September of that year, which would surely bring the world to an end. The masses were terrified but of course the year passed without anything happening. But the people were not allowed to escape from the fear of impending disaster for just ten years later another alarm was raised when it was said that the anti-Christ had been born in Babylon and all the human race must perish.

It would be interesting to make a list of all the years in which the people of the ancient and mediæval world have gotten ready to face the complete destruction of their planet. These years might be counted by the hundreds. It is a sad commentary on civilization to think that the astrologers and alchemists were able to get the people keyed up to the point where, at the arrival of the appointed hour, they would all sit down, fold their arms and await the destruction of the universe.

Such a scene was enacted in 1335 and again in 1524 when the planets Saturn, Jupiter and Mars were in conjunction in the Sign

of the Fishes, which was supposed to mean that the world was to be destroyed by a flood in February of that year. To modern people such a conjunction means nothing. In 1933 Venus, Jupiter, Mars and Neptune were in conjunction in the Sign of Leo and not a word was said about it. In fact no one knew it except the astronomers but at the time of the conjunction of the three planets in 1524 the people of the civilized world were thrown into a state of consternation. Many of them sold their lands for what they could get out of them and built boats patterned after Noah's Ark in order that they might be able to take care of themselves and their families when the day came. At last February came and went without a drop of rain. Although the people were thoroughly disappointed because they had lost an opportunity to try out their boats they were soon busy getting ready for the end of the world which was now set for 1532.

TEMPORARY STARS ANNOUNCED THE END OF THE WORLD

All through the Middle Ages the astrologers, soothsayers, crystal-gazers, seers, mind readers, mystics, and voodoos insisted upon doing the scientific thinking for the masses. Their methods were very similar to those used today but they were much more successful then because the masses were densely ignorant. Very few people were then interested in the universe about them because they felt sure that this world would not last very long and they naturally concentrated their attention upon another world which they hoped to find ready-made.

In 1572 a bright temporary star—now known as Tycho's Star—blazed out in the constellation Cassiopeia, which was so brilliant that it could be seen in full daylight. The astrologers immediately announced that this was the return of the Star of Bethlehem that had come to announce the second coming of Christ. They announced that the world would come to an end in 1588 and the masses were firmly convinced that they had only sixteen years to live. Of course nothing happened during that year. Another temporary star blazed out in 1604—Kepler's Star—which again threw the people into consternation. The

most recent brilliant temporary stars appeared in 1901 and in 1918, but by this time the astrologers had lost their influence over the masses.

The world was supposed to end many times during the seventeenth, eighteenth, and nineteenth centuries. In 1826 the announcement was made that the end would come in the year 1836. It was argued that Jacob was born in 1836 B.C. so that the ancient church had lasted eighteen hundred and thirty-six years. Consequently the new church will exist the same length of time and the world would end in 1836 A.D. Of course nothing happened in that year but in 1840, after the astrologers had had four years to recover from their disappointment, the end of the world was predicted for the year 1900. Nothing happened in 1900 but it seems to be absolutely necessary for some of the fanatics to have a fixed date to which they can point as a date of the final destruction of the universe, so we sometimes hear the date 2000 A.D. mentioned as a year beyond which the universe certainly cannot exist. If people are still living on the earth at that date, then they may expect nothing to happen before 2537 A.D., a date that was suggested by one of the early theologians because there are 2537 verses in the Psalms.

WORLDS, LIKE MORTALS, MUST DIE

When some twentieth century crystal-gazer or astrologer announces the approaching end of the world we merely smile and forget it. Yet from a scientific point of view the end of the world must eventually come. Worlds, like human beings, are born, live their allotted time and finally die. Our world may come to an end in several different ways and it is well to investigate each of these but the scientists tell us that, so far as they can now determine, the danger is rather remote.

Like all of the other stars, our sun is moving through space and is carrying us at the terrific speed of twelve miles a second toward the part of the sky now occupied by the star Vega. Collisions between individual stars actually do occur, as evidenced by the temporary stars that blaze out in the sky from time to time. If our star—the sun—should collide with some other star

somewhere in the depths of space, the entire solar system would be blotted out of existence and a new solar system would be formed. Of course all human life would then come to an end, but the average person is not losing much sleep over this impending disaster for the stars are so far away that our astronomers could give us warning at least a century in advance.

When Kepler announced that the earth was moving around the sun in an oval curve, which brings us closer in January than at any other time of the year, it was thought the shape of this orbit constantly remains the same so that our distance this January was exactly the same as it was a year ago. But during the eighteenth century the mathematicians discovered that the shape of the orbit of the earth was changing so that each year we pass closer and closer to the sun. Serious-minded people immediately raised the question as to whether this would not result in the earth finally falling into the sun, in which case the entire human race would perish by fire. Such a calamity would certainly befall the human race if this flattening of the earth's orbit continued forever but fortunately the mathematicians have proved that the change in the orbit is periodic so that the earth will always remain at a safe distance from the sun and we need not worry about falling into this celestial furnace.

THE HUMAN RACE WILL DIE OF THIRST

No discussion of the end of the world would be complete without some reference to the possibility of our freezing to death. Most of us go about our daily affairs unmindful of the fact that, as the earth swings around the sun in its annual orbit, we are held in our proper place by the invisible chain of gravitation. We do not know what gravitation is but we owe our very lives to the existence of this force. If at any time during the year gravitation should release its hold upon the earth we would fly off at a tangent and the entire human race would freeze to death out in the depths of interstellar space. However, since the force of gravitation can be seen to operate throughout the length and breadth of the universe and we have not yet discovered any case where it has fallen down on its job, we do not worry much about this possibility.

The earth must inevitably be robbed of its water and the human race will perish from thirst if it is not blotted out of existence by some catastrophe. The smaller the planet the sooner it ages and loses its atmosphere. The moon has already reached this stage and so has the smallest planet, Mercury. Mars is somewhat larger than Mercury, but smaller than the earth and seems to have very little water on it. The oceans on the earth are being silently lifted into the air but not all of this water returns as rain. Geologists tell us that the earth is much drier now than it was ages ago. Much of its surface is now desert waste and these deserts seem to be widening.

It is a matter of deep concern to the human race that deserts have begun to exist on the earth, but there need be no immediate alarm. Thousands of centuries must elapse before the earth will reach that stage when its atmosphere will be entirely missing. By that time the human race will probably have entirely disappeared and the earth will be revolving about the sun with the same face always turned toward that central luminary as Mercury does now. There will then be no sunrise or sunset. There will be no day and no year and time itself will have come to an end as far as the earth is concerned, because there will be nothing with which to measure it.

MANY WORLDS ARE PROBABLY INHABITED

Are the other worlds inhabited? Are there any people on the neighboring planets who are perhaps at the present moment studying the earth with their telescopes, spectroscopes and other kind of "scopes" and wondering whether our earth, which must appear to them as a small star-like object, really has any human beings on it? Does our little earth have a monopoly on the life germs in the universe or are they not perhaps also to be found upon the millions of planets very similar to the earth that exist throughout the heavens?

Before we can answer any of these questions in a satisfactory manner we must first make much progress in the science of astronomy. However, as the universe unfolds before us and our conception of space becomes broader we are forced to admit

the possibility of life being scattered everywhere throughout the universe.

Man's ideas about his own importance in the universe have undergone quite a change since he first began to take note of his surroundings. There was a time when he felt that he was the object of creation and that if he were not on the earth the sun, moon and stars would not be in the sky for there would be no need for them. For a long time he believed that the earth was at the center of the universe and the sun, moon and all the other heavenly bodies were moving around the earth for his comfort and amusement. Naturally there was no thought of any life being anywhere except on the earth. About four hundred years ago man was forced to give up his position at the center of the universe and to admit that his earth was only one of several worlds, all of which were revolving around the central sun. After Venus, Mars, Jupiter and all of the other planets had been placed on an equality with the earth, he was forced to admit that there was a possibility of the existence of life on some of these companion worlds.

In order that a heavenly body may support life it is not necessary that the same conditions exist there that are found here on the earth, or that the forms of life existing there resemble in any way those with which we are familiar. In other words, in order to be inhabited a body need not be just like the earth.

MAN'S UNIVERSE CONTINUES TO EXPAND

While man was attempting to adjust his philosophy of life to an existence on a little planet belonging to the central sun, his universe continued to expand until he discovered that the gigantic sun about which the earth and the other planets revolve is nothing but a star and a very small star at that. He soon learned that every star is a sun and that most of them are larger than his own sun. After having discovered other worlds revolving about other suns, he can see no reason why every star in the sky should not be accompanied by a system of worlds such as he finds going around the star to which he belongs.

Man has at last come to realize his own insignificance in the

universe. He is fully aware that his little earth is merely a speck in the universe, whose complete destruction would have no effect whatsoever upon the appearance of the heavens with the exception of the moon. At one time he believed that the earth was rather large and that a trip around the world would be quite an undertaking. He now understands that the distance from the earth to Neptune is equal to more than a hundred thousand trips around the world and yet Neptune belongs to the same star to which he belongs. When he tries to picture in his mind the distances from the earth to the worlds that go around the other stars his imagination cracks and he is willing to admit that these other worlds have as much right to be inhabited as his own. Surely they are just as important as the earth.

Among those myriads of other worlds in the boundless universe surely there is at least one that is inhabited by some form of life. Would it not be interesting to establish communication with these distant worlds and learn something about their forms of society, their religions and their everyday life?

Certain conditions are necessary in order that a celestial body may support life and if we find these conditions existing on any celestial globe we may be fairly certain that life of some kind will be found on it. The body must be cool enough to have a stable crust, it must have a certain amount of atmosphere, and it must be near enough to the source of heat for a temperature sufficiently high to support life.

LIFE MAY EXIST IN MANY FORMS

As we examine various worlds for signs of life we are merely trying to determine whether there is any living thing on them. We are not necessarily looking for human beings, for there may be living beings on some of these planets that would not be recognized by us as being human. Life is a creature of its environment and human life as we find it on the earth is probably entirely different from life as it exists on any other world in the solar system because these worlds differ so widely.

Even on our own world we find a great difference between people living in different localities. A race of people planted on

the equator and living there generation after generation will not resemble in many respects another race planted near one of the poles of the earth and developing there through many generations. How long would an Eskimo live if he were transplanted into the jungles of our tropics?

Suppose we should succeed in establishing communication with a race of people brought up on a planet that is entirely separated from our own—a world that receives its light and heat from the same celestial furnace that is used by the inhabitants of the earth, but having no physical connection with our planet. These people would certainly have a system of government of a type about which we have never heard and their manners and customs would be strange to us. They would know nothing of the beautiful myths and legends of classical literature nor of the many critical events which have been recorded by our historians since man has been on the earth.

These neighbors of ours would speak a strange language and even if we could understand each other we would probably find it difficult to carry on a conversation for we would have nothing in common to talk about. Neither of us would know anything that had ever happened on the world on which the other person lived. We could not discuss the weather, government or politics, neither could we get together on religion for our neighbor—though he might worship the same God—would be ignorant of the different forms of religion that exist on the earth. He might even be able to offer us a new religion that would be more satisfactory than any of the different types that are offered inhabitants of the earth today.

THE MOON IS NOT INHABITED

In our search for life in other worlds we naturally begin with our nearest neighbor. Does anybody live on the moon? We know more about the surface of the moon than that of any other heavenly body. Since the surface of the earth consists of both land and water it was natural for man at one time to believe that the dark areas on the moon were seas and that the light areas consisted of dry land. After he became better acquainted with

the moon, he discovered that it had no atmosphere and consequently no water, either in liquid or gaseous form, so that the possibility of our satellite being inhabited seems very remote.

Since there seems to be no air, no water and no vegetation on the moon surely life as we know it could not exist on that little globe. If it ever has existed in the past it must have disappeared long ago. There are no lunar clouds to cut out the terrific heat of the sun which beats down on the surface of the moon for fifteen of our days. There is no rain to bring new life to the parched landscape and no cool winds can bring relief from the cold side of the moon. Under conditions such as these the temperature would probably rise to at least 250 degrees Fahrenheit.

After the sun had finally disappeared the heat would rapidly be dissipated into space, since there is no atmosphere to hold it, so that during the long lunar night of more than 350 hours the temperature would probably drop far below zero. The surface of the moon must, of necessity, expand and contract every month so that huge masses of rocks must be continually breaking off and falling silently down the sides of the mountains. Surely, under conditions such as these, no one would contend that life as we know it could exist on our companion world.

For more than 300 years the moon has been subject to constant telescopic examination and we are sure that there has been no change in its surface during all of this time. Its diameter is much smaller than that of the earth and it has cooled off and dried up much more rapidly. In fact, its life history seems to have ended and everything seems to point to the fact that the moon is just a huge rock, not inhabited by any living thing.

MERCURY SEEMS TO BE A DEAD WORLD

Is there any life on Mercury—the little world that flits back and forth from one side of the sun to the other? Perhaps you wonder why the problem of life on other worlds that belong to the sun has not been solved. You may ask, "Why do not the astronomers look at these worlds through one of the large telescopes and tell us whether or not people are living on them?" As a matter of fact, it would be just as easy to settle this question

by looking through a telescope as it would be to determine whether anybody is living in the United States by making a relief map three inches square and looking at it while we hold it at arm's length. We cannot hope to actually see the inhabitants of any other world. We can only prove that people are living on a planet by observing cities or some of the other things that they have created.

The rotation of the earth carries us every evening into the restful shades of night, but if Mercury ever rotated on its axis something has retarded its rotational speed until it now keeps the same face toward the sun all of the time. One side of the planet is always bright and the other side is always dark. From our position on the earth we can see only the daylight side and we find that this little world has no atmosphere and that its surface is covered with cracks which are probably due to the terrific heat.

On one side of the planet there is a never-ending day, with the sun beating down upon it with seven times as much heat and light per unit area as we get on the earth and with no atmosphere to furnish protection from its brilliant rays. Surely the daylight side of Mercury with a temperature of 1100° F.—lead would melt here—must be burned to a cinder. The other side of Mercury is immersed in eternal night and is probably frozen solid at a temperature several hundred degrees below zero, for there is no rotation to give relief from the intense cold and there are no air currents to bring the heat from the scorched side of the planet to the frozen side. Surely we would hardly expect to find human beings or life of any type on a world without any water or atmosphere and under the conditions of temperature that exist on Mercury.

VENUS PROBABLY HAS LIFE ON IT

Since Venus is the twin sister of the earth with an atmosphere very similar to ours the question naturally arises—do people live on that planet? Is there any life on yonder world which shines so beautifully in the evening sky? Although Venus is more favorably situated for observation than Mercury we know even less about its surface for it is always hidden by clouds that seem

to be floating in a rather dense atmosphere. It is for this reason that Venus shines so brightly.

Astronomers have not yet been able to agree as to the length of the rotation period of Venus. If it should be finally determined that Venus has a day of about twenty-four hours—and many people believe this to be the case—there would be very little question as to the existence of life on that world, and the forms of life on the twin worlds should have many characteristics in common.

Even if Venus does keep the same face toward the sun conditions would be very different from those on the parched planet Mercury and it is conceivable that certain forms of life might exist both on the daylight side and also on the dark side. Although one side of the planet would be always in the daylight and the other side in perpetual darkness the dense atmosphere would, to some extent, protect the daylight side from the piercing rays of the sun and would furnish refreshing rains. It would also carry the air from one side of the planet to the other and in this way the dark side would be warmed by air currents which, after they had been cooled, would return to relieve the heat on the other side.

No one would imagine for an instant that after the Creator had constructed this magnificent solar system—nine worlds revolving around a central sun—He would have selected our little globe to be the abode of life and overlooked its twin sister and neighbor, Venus. Surely there must be some forms of life on Venus that are not so very different from what we find on the earth. The objection has been raised that Venus is too near the sun to have life on it. It is true that Venus is a little warmer than the earth, but this is no barrier. We have life at the tropics and also life at the poles.

PEOPLE PROBABLY LIVE ON MARS

There are certain requirements for the existence of life on any planet and on Mars all three of these requirements appear to be fulfilled. This little world certainly has a solid crust for there are many permanent markings on its surface that can be

very easily observed as the planet rotates. Mars has an atmosphere similar to the one in which we live, although it is not quite so dense, and it is close enough to the sun to be able to use the same source of light and heat that we use. Mars has a day almost exactly twenty-four hours long and four seasons in every year just as we have, although they are about twice as long as our seasons. If there are any human beings on Mars they must have water somewhere on the planet and the behavior of the white polar caps convinces us that there is water on this little world. Some people claim, however, that the material at the poles of Mars may be frozen carbon dioxide, the same substance that we call "dry ice."

What if Mars has reached such an advanced stage in its history that there is no water except at the poles? The Martians would not die of thirst without making a supreme effort to distribute this water over the planet. Some astronomers claim that they can see certain thread-like markings on the surface of Mars which they interpret to be canals that have been constructed by intelligent human beings for the purpose of tapping the water supply at the poles. This would not be such a stupendous undertaking, for the Martians—if they exist at all—are living in a much more advanced civilization than we find on the earth. The smallness of their world would also be in their favor because of the diminished force of gravity. Twice as much work could be done with the same amount of energy as on the earth. And besides there are no mountains on Mars.

More and more astronomers are coming to the conclusion that if life does not actually exist on Mars today it has existed there at some time in the past, although it seems absolutely impossible to definitely prove this fact. It seems that this planet has cooled off much more rapidly than the earth so that Mars will soon roll through space a dead world, its career forever ended.

HUMAN BEINGS COULD NOT LIVE ON JUPITER

It seems hardly necessary to raise the question as to whether any life exists on the planets Jupiter, Saturn, Uranus and Neptune. Jupiter is surrounded by heavy clouds that rotate at differ-

ent speeds in different latitudes and it is extremely doubtful whether we have ever actually seen the surface of the planet—if indeed it has any surface. Many scientists are of the opinion that these giant worlds do not have solid crusts upon them, but even if they do they are so far from the sun that they could not support life similar to what we find on the earth for, unless they have some internal source of heat, the temperature on their surface cannot be greater than 400 degrees below zero Fahrenheit. If we should ever discover a race of people on Jupiter we may be sure that they will be pigmies because of the great force of gravitation on that planet. If a human being should move to Jupiter he would be so heavy that he could scarcely walk about.

What has been said about Jupiter, Saturn, Uranus and Neptune applies equally well to the newly discovered Pluto, whose surface temperature is probably almost as low as “absolute zero.” In fact, the very air that we breathe would be frozen solid on Pluto. It seems highly improbable that either of these worlds has life on it at the present time and if a life germ should be planted on one of them later it would develop into something entirely different from what we have on the earth because conditions there are so different from those to which we are accustomed.

Twenty-six moons circle the different worlds in the solar system and several of these are larger than the planet Mars. Is there any life on these satellites? Nothing is known of their physical condition except in the case of that particular one which revolves about the earth. We know that our own moon is not inhabited and we might rule out about fourteen of the other twenty-five on account of the fact that they are so very small, but we cannot even make a guess as to the probability of the existence of life on the others. Of course some of these are so far from the sun that they would not receive much heat, but we are not absolutely sure that they do not have some internal source of supply.

LIFE ON THE STARS WOULD BE IMPOSSIBLE

When we examine one by one the nine planets in the solar system in our search for life on other worlds than ours we are

finally forced to the conclusion that only two of these—Mars and Venus—could possibly sustain life, that is in any way similar to those forms that exist on the earth. It seems that not one of the 1200 little planets that circle the sun between the orbits of Mars and Jupiter is as large as 800 miles in diameter so that we need not expect to find here the conditions that are necessary to support life. Neither would we expect to find life on comets, meteors, or shooting stars. Of course we need not consider the sun itself for nothing could exist except in the gaseous form in a temperature of 6000 degrees and any life germ that might get within several million miles of the sun must surely burn up.

The problem of determining whether or not some form of life exists in other parts of the solar system besides the earth may not be solved for many years, but when one contemplates this gigantic celestial machine with its nine planets, twenty-six moons, 1200 planetoids, hundreds of comets, and millions of meteors he naturally comes to the conclusion that either there is life on some of these neighboring worlds or the sun is carrying on its business in a very wasteful manner. The sun is the controlling member of the solar system. It furnishes all of the heat and light and serves as the motor that makes the machine run. From its position at the center of the solar system the sun pours forth torrents of heat in every direction, enough heat to warm two thousand million globes as large as the one on which we live. If the solar system was created for the comfort and the amusement of the inhabitants of the earth and the sun was designed solely for the benefit of humanity, this gigantic heat engine is certainly not operating with one hundred per cent efficiency.

Is there any life on yonder stars that twinkle so brightly in the winter sky? Scientific research has convinced us that every star is a sun and many of them are larger and hotter than the sun that controls our own solar system. Surely life on the stars would be impossible.

THERE MAY BE LIFE ON OTHER GALAXIES

Most of the stars are larger than our sun and we have every reason to believe that they are attended by planetary systems—

some of which we have already discovered—that greatly exceed our own both in dimensions and in numbers of planets. But you ask, “Why do not the astronomers turn their telescopes on these stars and make a study of these planetary systems?” You have perhaps lost sight of the fact that these stars are at an enormous distance from the earth. If you were living on a planet that belonged to the nearest star you would be thirty million million miles from our solar system and, although you might have a very powerful telescope, you would never discover that our sun, which to you would resemble a star, had a system of worlds going around it.

Astronomers tell us that there must be thousands of planetary systems in the universe where conditions would not be very different from those that we find in our own solar system. Why then should not life exist on one or more of these planets revolving around other suns? Again, when we consider other galaxies that are composed of stars like our own sun we naturally wonder whether among the millions of stars composing these galaxies there are not some like our sun attended by planets fitted to be the abode of life and actually inhabited. We cannot at the present time give a definite answer to this question. We merely ask, why not?

When one goes out of doors on a clear moonless night and his attention is attracted to the wonderful work of his Creator as exhibited in the heavens, surely he cannot be so narrow as to feel that this gigantic universe, with its millions of suns and solar systems, was constructed and is being maintained solely for the benefit of the inhabitants of this little earth which is such an insignificant part of the whole. Have we a right to assume that our little earth is the only body in this multiplicity of galaxies where conditions are such as to support life? We must depend upon science to answer this question for us in due time. Has not science already weighed the stars, explored the atom, annihilated distance, and viewed the invisible? Just think of the progress we have made in the three centuries since Galileo first pointed his little two-inch telescope into the sky!

WE STILL WONDER

We are living in an age of wonders. Our scientists are daily performing miracles even greater than those described in the early literature of the human race. Yet man seems not to be any nearer the end of his search for knowledge. Many discoveries have been made but much more yet remains to be learned. This is true of almost every branch of human knowledge.

There was a time when man, because of his dense ignorance, felt that he knew all there was to be learned about the heavens. Astronomy was a finished science and even if it were not—well, the world was coming to an end very soon anyway, so why worry? The discoveries of Copernicus brought about a revolution in man's ideas and astronomy has made rapid progress since that great Polish scientist dared to state that the earth was merely one of a number of small planets that silently and faithfully play their minor roles in the Drama of Space in obedience to the mandates of their lord and master—the sun.

Who can visit a modern astronomical observatory without being impressed by the development and improvement of the instruments for astronomical research? Under the huge dome we find the powerful telescope driven by an electric clock with such accuracy that it will follow the path of a single star directly across the sky. Mounted exactly in the meridian is the transit with its electric attachments for recording the passages of stars across the meridian and thus regulating our clocks. Without the transit instrument modern transportation would be impossible. In the Observatory will also be found the spectroscope which reveals the chemical composition of the heavenly bodies and tells how fast they are moving, and the instruments for photographing "invisible" sections of the heavens that the eye could never see.

It is true that we have made rapid progress along astronomical lines and have solved many of the riddles of the universe. However, the question as to whether life exists on our neighboring planets in the solar system and on the other planets that revolve around other suns seems to be as far from being solved today as it was in the time of Copernicus. Today we can only conjecture, but perhaps tomorrow some new invention will solve

this problem for us just as the spectroscope during the latter part of the nineteenth century revealed to us the chemical composition of the distant stars.

THE PURPOSE OF UNIVERSE HAS NOT YET BEEN REVEALED

Who can contemplate our universe of gigantic galaxies and minute atoms without wondering what is the purpose of it all? Were these things created for our benefit and enjoyment or was man merely a by-product of the creative process? It was at one time thought that the stars and planets were interested in mankind and held secrets about his future life. Many a king has employed astrologers to read the stars and tell him something about his future. In fact, Kepler is said to have made his living as an astrologer so that he might have sufficient funds to study astronomy.

We are now sure that if man had never been planted on the earth there would still be just as many planets revolving round the sun and just as many electrons revolving round a nucleus of calcium. There would be just as many stars in the sky and these stars will exist long after the human race has disappeared. If the universe exists for any definite purpose as far as human beings are concerned, this purpose has not yet become apparent.

We are told that gravitation holds in their proper positions the huge heavenly bodies that compose a galaxy and that electricity controls the behavior of the minute electrons that compose the atom. Both of these concepts are beyond our senses, one because it is too large and the other because it is too small, and they are both controlled by invisible forces which we choose to call gravitation and electricity—neither of which we can define.

Modern man has learned that his own body is composed of electrons and atoms exactly like those that are to be found in the stars, in the sun and in all other parts of cosmic space. This is the picture of the universe as revealed by the scientific minds of the twentieth century and what a glorious universe it is. Who can imagine a God great enough to preside over such a cosmos? The more a man knows about the miracles of science and about

the universe that is around him and above him the more religious he becomes and the more respect he has for his Creator. Surely the forward march of science from the time of Copernicus down through the ages to the present day has been the greatest systematic search for God that the world has ever known.

MAN'S IDEA OF GOD CHANGES WITH THE UNIVERSE

As we study the furniture and framework of cosmic space and learn that it is composed of galaxies which we cannot comprehend, some because they are too large and others because they are too small, we naturally get a different idea of our Creator than we ever had before. Every new scientific discovery increases our admiration and respect for an invisible power which can rule over such a multiplicity of galaxies.

We are no longer interested in a carpenter God who created the earth and placed above it the broad expanse of the heavens in which the stars and constellations might be displayed. The early ideas as to the relation of the sun, moon and stars to the earth have had to give way to science and the God of primitive peoples will not fit the vast universe of the twentieth century.

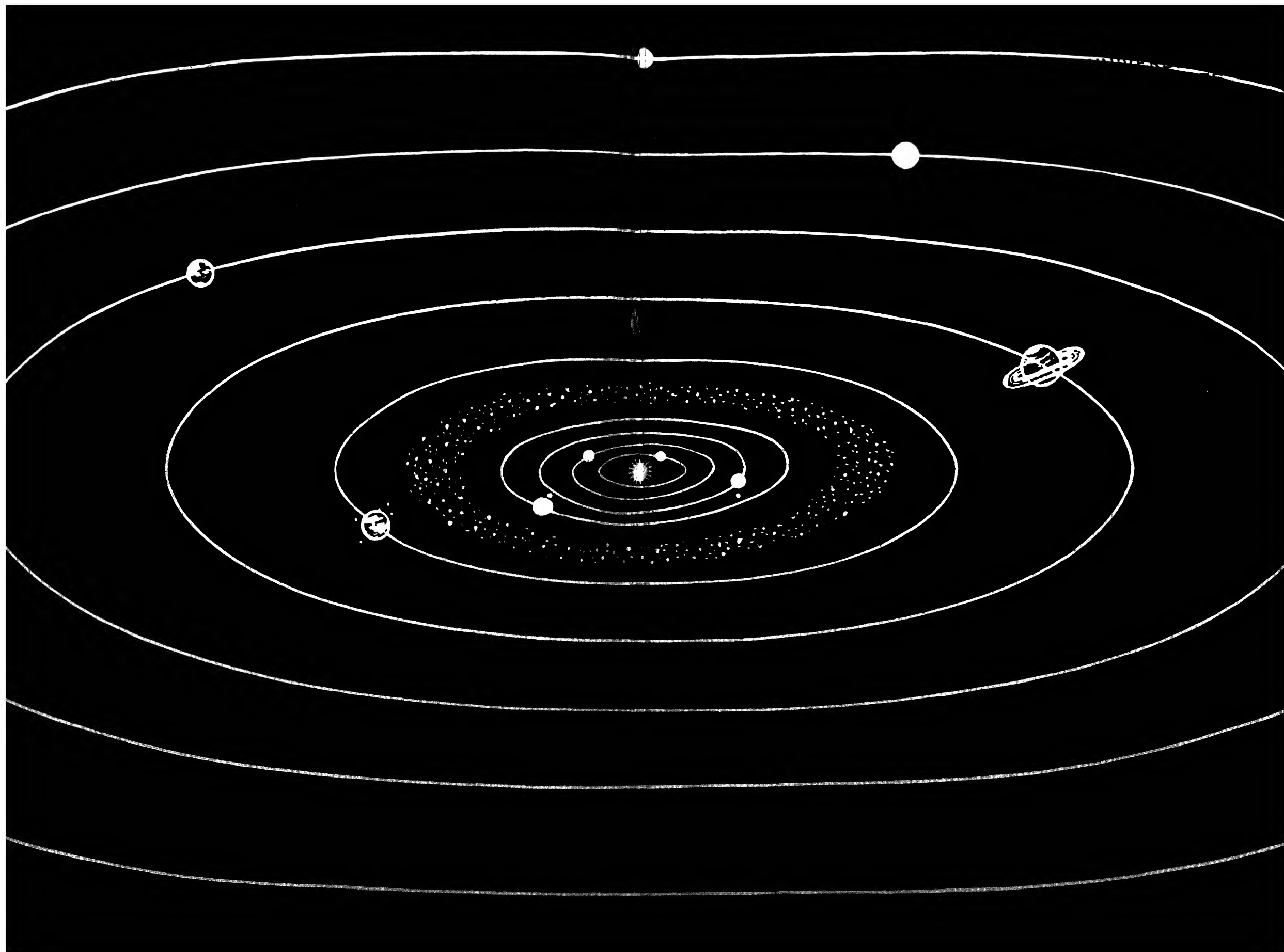
We now think of a Creator who built the earth to be our place of abode, but while He was doing so He also created eight other worlds that go round the sun. He put twenty-six moons in their proper positions around these different worlds, He put the rings on the planet Saturn. He placed the 1200 asteroids in a ring completely surrounding the sun, and He created the other suns—we call them stars—most of which are much larger than our own gigantic sun. In fact He not only built this gigantic galaxy of ours out of planets, suns, moons, star-clusters and nebulae, but he also constructed the hundreds of thousands of other galaxies that we find scattered through space. Then the Creator built the atom, which is merely a microscopic solar system, in order that man might realize his insignificance and appreciate the fact that there is just as much of space, relatively speaking, that is too small for him to observe as that which is too large for him to comprehend.

The study of astronomy gives a man a much broader and grander conception of his Creator, and his idea of that invisible hand, which is continually guiding the universe, changes as his knowledge increases. His universe continues to expand with each succeeding age and man naturally leaves behind his primitive ideas about a Creator who devoted all of His time and attention to this little earth, and dreams of a God with sufficient power and wisdom to guide and direct the stupendous universe which science has revealed in the twentieth century.

PRONOUNCING GLOSSARY

Achernar (<i>a-ker-nar</i>)	Enceladus (<i>en-sel-a-dus</i>)
Alcmene (<i>alc-me-ne</i>)	Eros (<i>e-ros</i>)
Aldebaran (<i>al-deb-a-ran</i>)	Europa (<i>u-ro-pa</i>)
Altair (<i>al-ta-ir</i>)	Fomalhaut (<i>foam-ul-hote</i>)
Andromeda (<i>an-drom-e-da</i>)	Gaea (<i>je-a</i>)
Antares (<i>an-tay-res</i>)	Galileo (<i>gal-i-le-o</i>)
Apollo (<i>a-pol-o</i>)	Ganymede (<i>gan-i-med</i>)
Aquarius (<i>ak-ware-ee-us</i>)	Gemini (<i>gem-in-nee</i>)
Aquila (<i>a-kew-la</i>)	Helios (<i>he-li-os</i>)
Arctos (<i>ark-tos</i>)	Hyades (<i>hi-a-dez</i>)
Arcturus (<i>ark-tu-rus</i>)	Hyperion (<i>hi-pe-ri-on</i>)
Ares (<i>a-res</i>)	Io (<i>I-o</i>)
Aries (<i>air-eez</i>)	Libra (<i>lee-bruh</i>)
Ariadne (<i>a-ri-ad-ne</i>)	Medusa (<i>me-du-sa</i>)
Auriga (<i>oh-rye-juh</i>)	Oberon (<i>o-ber-on</i>)
Betelgeuse (<i>bet-el-geuz</i>)	Olympus (<i>o-lim-pus</i>)
Boötes (<i>bow-oh-teez</i>)	Ophiuchus (<i>o-fy-you-kus</i>)
Callisto (<i>cal-lis-to</i>)	Orion (<i>o-rye-on</i>)
Canopus (<i>ka-no-pus</i>)	Osiris (<i>o-si-ris</i>)
Capella (<i>ca-pel-la</i>)	Pallas (<i>pal-as</i>)
Capricornus (<i>cap-rec-korn-us</i>)	Pegasus (<i>peg-a-sus</i>)
Cassiopeia (<i>kas-i-o-pe-ya</i>)	Perseus (<i>per-se-us</i>)
Cepheus (<i>se-phe-us</i>)	Phaeton (<i>fa-e-thon</i>)
Ceres (<i>se-rez</i>)	Phoebe (<i>fe-be</i>)
Cetus (<i>se-tus</i>)	Phobos (<i>fo-bos</i>)
Chaos (<i>ka-os</i>)	Pisces (<i>piss-eez</i>)
Chronos (<i>kron-nus</i>)	Pleiades (<i>ple-a-dees</i>)
Clytie (<i>kli-ti-e</i>)	Polaris (<i>po-lar-is</i>)
Copernicus (<i>ko-per-ni-kus</i>)	Praesepe (<i>pre-se-pe</i>)
Cygnus (<i>sig-nus</i>)	Procyon (<i>pro-cye-on</i>)
Daphne (<i>daf-ne</i>)	Proserpina (<i>pro-sur-pi-na</i>)
Deimos (<i>di-mos</i>)	Regulus (<i>reg-u-lus</i>)
Dione (<i>di-o-ne</i>)	Rigel (<i>ree-jel</i>)

Sagittarius (<i>saa-jit-tare-ee-us</i>)	Tuesco (<i>tu-es-co</i>)
Saros (<i>sa-ros</i>)	Umbriel (<i>um-bri-el</i>)
Scorpio (<i>skor-pee-oh</i>)	Uranus (<i>u-ra-nus</i>)
Sirius (<i>sir-i-us</i>)	Vega (<i>vay-ga</i>)
Spica (<i>spy-ka</i>)	Virgo (<i>vur-goh</i>)
Taurus (<i>toh-russ</i>)	Vulpecula (<i>vul-pek-u-la</i>)
Tethys (<i>te-this</i>)	



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